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# JOURNAL OF FARM ECONOMICS

Volume XLIII FEBRUARY, 1961 Number 1


## GUIDELINES FOR A CONSTRUCTIVE REVISION OF AGRICULTURAL POLICY IN THE COMING DECADE[1]


KARL BRANDT

*Member of the President's Council of Economic Advisers*


I BELIEVE it to be one of the legitimate functions of economists that they make their contribution to the development and performance of our political economy by putting before the American people, their legislators and administrators alternative courses of policies and by evaluating comparative costs, major results and expectable side effects. It is for the body politic to choose and decide. It is the economists' duty to keep the body politic well informed, first of all on the range of alternative means to arrive at certain ends. In this sense I put an additional alternative set of guidelines on the docket of our profession for preliminary discussion and for later testing and weighing against a number of other alternative packages of farm policy measures. These guidelines are not presented at this time as a recommendation for political consideration.

Studies of agricultural policy issues on both sides of the Atlantic stretching over 35 years have taught me that the "agricultural problem" is in all countries a perennial part and parcel of the dynamic process of economic development and of the dislocations and adjustments which are integral elements in it. Under any democratic form of government, farm policy tends to become an increasingly hot political and social issue as the accelerated rise in productivity of manpower in agriculture requires people to shift from rural to urban employment. The ever-changing symptoms of the farm problem can be tackled by an unlimited variety of public policy programs. But the hard core of the farm problem, namely, the

[1] *Editor's note:* This paper was presented before the Annual Meeting of the Western Farm Economics Association, Stanford University, August 25, 1960. It is reproduced here at the suggestion of the then President of WFEA that it merits "a wider distribution than it would get from being printed only in the proceedings of the Western Farm Economics Association, and that members of the American Farm Economic Association would generally be interested in it." We are grateful to the Western Association for making this paper available to our readers.

structural change involved in a nation's economic growth can never be "solved" in the same sense as one can solve problems of a temporary emergency nature. Being concerned chiefly with the social impact and pains of economic growth, the legislative treatment of the farm problem can diminish the political friction and heat it causes. However, it is well to realize that farm legislation reaches in all countries to the very life of liberty and the core of the values that orient an economic system, the more so the smaller the farm population gets. Farm legislation calls for warm hearts and cool heads.

## I

In the coming decade foreign affairs will outweigh domestic issues far more than in the past because our military security will depend heavily on closest cooperation with our allies. This in turn presupposes more and more economic cooperation within the Atlantic Community including Latin America, and with the free parts of Asia. These vital relations reduce the leeway for potential domestic adjustments by any measures of restriction of imports and of foreign exchange controls.

Compelling evidence makes it abundantly clear that in this turbulent and deeply divided world our country will face in the years ahead a most crucial test of its leadership among the free nations. To meet the challenge in all its interlocked diplomatic, military, political, and economic aspects requires that we develop, expand, and utilize our productive resources with drive, imagination, and wisdom. With an assured vigorous growth of our population, appropriate efforts at further improving health, education, and research, and continued thrift, formation and wise investment of capital of our citizens, the foundations for greater national security and welfare appear excellent. Provided the nation and its statesmen are alert and act with prudence, that is: given appropriate public policy, prospects are good that with growing productivity and a rising real output of goods and services per capita, the economy will offer ample opportunities to our people for a sustainable high rate of employment and for the improvement of income while we simultaneously discharge our heavy responsibilities in mutual security, foreign trade and investment, particularly in less developed countries.

However, it must be realized that such growth and performance of the national economy is bound to face a much harder competition in coming years than in the period since the end of World War II.[2]

To assure a continued stable and prosperous development of the Western countries requires that the stability of convertible currencies, recently

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[2] Cf. Karl Brandt, "Economics Abroad—Beginning of a New Era," 18th Stanford Business Conf. Disc. Paper, July 20, 1959 (Mimeo. by Board of Governors, Federal Reserve System).

achieved, be extended, and that foreign trade be liberalized further. This puts a high priority on the maintenance of the integrity of the U.S. dollar as the world's foremost reserve currency. Only if we succeed in containing inflation in the domestic economy will it be possible to hold the balance of trade and the balance of payments in such conditions that the dollar remains a hard, freely convertible currency, and that a liberal foreign trade policy prevails.[3]

Due to the strong revival and vigorous expansion of the industrial exports of Western Europe and Japan, there will be less latitude for price increases of U.S. products than during the postwar years in which U.S. industries had a practical monopoly of supply. Increasing competition from Soviet Bloc countries in world trade and in financing of underdeveloped countries will make domestic price stability even more mandatory lest unemployment hit industries that have priced themselves out of their foreign markets.

If these assumptions about the changed impact of the international situation on our national economic policy should be basically correct, it would demand even more than in the past that productive resources be allocated to the uses where they contribute the optimal yield to the social product. In a dynamic economy this calls for a high mobility of resources. Most of all, it calls for the geographic and vocational mobility of the greatest of all resources: manpower.

Within the American economy a universally unique feature of our dynamic progress is the structural improvement and the unprecedented rise in productivity in agriculture. These have yielded a steady flow of labor to the urban economy, and assured for it an abundant and dependable supply of food and fibers at reasonable prices. In its utilization of land and capital resources and its output agriculture is today an extremely well-integrated part of the national economy, which performs in accord with economic principles as any other part of it. Originally, nearly all other economic activities were integrated into agriculture, as is best illustrated by the fact that in Jefferson's time 90 percent, sixty years ago 50 percent, of the American population were gainfully employed in agriculture. Today less than 10 percent are still in agriculture.

The farm problem is commonly considered as the result of a sudden revolution or explosion of technology. There is, indeed, a great deal of improvement in machines, tools, plants, animals, feed, and fertilizer. But

[3] The realism of this observation voiced in August has since been confirmed and verified by the hectic gyrations of the price of gold in the free European and the Canadian markets in late October and early November 1960 and the cooperative actions of central banks and treasuries on both sides of the Atlantic and President Eisenhower's directive to the Secretaries of State, the Treasury, Defense, and Agriculture, and the Board of the Development Loan Fund to cut overseas spending or adjust operations to the necessity of adjustment of the balance of payments.

the essence of the change lies in improved input-output ratios and cost-revenue ratios. The persistence of very powerful price relations between factors and products has forced cumulative shifts in the operations of the firm in agriculture. The much steeper rise of farm wages than of total operating costs of labor-saving machinery has induced the continued substitution of capital for labor. The heavy capital investment in farm machinery and the economies of scale possible in its full utilization have led to acreage enlargement of operational units. The high excess of marginal revenues over marginal costs, still attainable anywhere in the U.S. in the application of more fertilizer and water to crops and pastures, has led to the boosting of yields per acre, or the substitution of purchased inputs for land. In fact the main increase in the output of crops during the last two decades can be explained by increased input in seed, pesticides, fertilizer (chiefly nitrogen), and water. This increase has contributed a considerable share to the increase of output per man-hour which was otherwise due to a reduction in input of labor. The institutional circumstance that for some major crops the supported market price is obtainable only for the output of a specified acreage allotment adds a further powerful economic incentive to increased use of yield boosting kinds of input. Allotments are, indeed, a powerful output accelerator.

As a result of these cost-price relations, which promote intensification and which governmental price supports have accentuated, the aggregate output has exceeded total utilization. This is the part of the farm problem that concerns the 2 million commercial farms and even more the U.S. Treasury.

Despite a large transfer of manpower out of agriculture, there is still a considerable excess of manpower left in agriculture. This is chiefly the problem of low-incomes of many of the people on the other 2 million farms, although by no means of all of them.

## II

Major economic defects of the methods chosen in agricultural legislation are the following:

A price guarantee for a few commodities interferes with the relations between prices of all farm products and all factors, and thereby interferes unintentionally with all supply responses of our agricultural economy.

Price support as the chief method of farm income support sets each support level above equilibrium and gives powerful incentive to excess production.

The raising of a commodity price above a competitive market level subsidizes non-agricultural producers of substitute products, such as man-made fibers, and competing farmers abroad, e.g. producers of cotton.

Both effects shrink the potential demand in domestic and foreign markets.

Insofar as agricultural exports must be subsidized, this is an additional drain of Treasury funds.

Due to excess production, support prices are actually fixed prices.

The guarantee against price changes for a select few commodities puts a premium on the risk-free expansion of their output.

Fixed grain prices vis-a-vis free livestock prices induce farmers to feed less and to sell more to the CCC as livestock prices fall.

Restrictive acreage allotments establish a premium on intensification and therefore are ineffective as output controls, while they tend to freeze the location of production.

Marketing quotas are more effective in controlling market supply of a commodity, but they shift the use of resources and thereby the surplus to other commodities. They are applicable and enforceable only for the part of the commodity stocks which are exchanged in the market.

The price-fixing legislation has resulted in truly gigantic stockpiles of unwanted grain and other farm commodities held by the Government, at enormous costs in interest, storage, losses, and transportation. This in itself is a perpetual serious misallocation and waste of scarce resources. It is a waste of a part of the taxpayers' income and has entrenched vested interests of third parties that benefit from surplus holding and handling.

Despite being sealed off from the current market, the excess stocks exert a depressive influence on the markets in the U.S. and the world, particularly in view of the prospect of continued excess production.

So long as this stockpile exists there is no possibility of restoring a free market for the commodities concerned.

The price supports, acreage allotments, and marketing quotas have raised land values and land rents and thereby created rigidities in land utilization and vested interests in the perpetuation of such policies. While increased equities benefit operating and retiring farmers, the higher land values increase costs for future farmers.[4]

The capitalization of revenues flowing from price support via acreage allotments increases the marginal physical and value productivity of land assets at the expense of returns to labor and capital assets.

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[4] Cf. Frank H. Maier, James L. Hedrick, and W. L. Gibson, Jr., *The Sale Value of Flue-Cured Tobacco Allotments,* USDA ARS Tech. Bul. No. 148, April 1960. This study lists for three North Carolina counties estimates of the sale value of an acre of flue-cured tobacco allotment separate from land and buildings as $1,290 for 1954 and as $2,500 for 1957. The same study found for 203 farm sales in one Virginia county a value for an acre of tobacco allotment in 1957 about 73 times as high as the value of an acre of cropland without the allotment.

Cf. also: Walter E. Chryst and John F. Timmons, "The Economic Role of Land Resource Institutions in Agricultural Adjustment," Seminar on dynamics of land use: needed adjustment, May 3-5, 1960, Iowa State University, Ames, Iowa.

The vast expenditures for price stabilization do not correct the regional maladjustment, such as the overproduction of wheat in the Great Plains, or the underemployment of manpower on the low-income farms of the Appalachian, the Piedmont, and the Ozark areas.

As a device for redistributing income to agriculture from within the economy, price supports are an inappropriate and wasteful means.

As a device to redistribute income within agriculture, price supports are even much less effective, because they prorate the increase in income according to the scale of operation.

Beyond outright donation, the disposal of surplus stocks can be achieved only by heavily subsidized exports, a policy which is counter to the national interest in a maximum liberalization of international trade.

The use of the surpluses under Public Law 480 as aid to underdeveloped countries is a costly *ex-post* method of assistance in which the recipient countries receive less than one-half of the costs to the U.S. Government, and in which it may perhaps recover no more than 10-15 percent of the costs after 10 to 20 years.[5]

Price support by the CCC by means of non-recourse loans and purchases amounts to an open-end commitment of the Treasury, which renders control over the government expenditures ineffective.

## III

In order to have some foundations on which to erect guideposts for a change, I offer a few observations on the essential features of the dynamics of agriculture.

There is no more than a minute grain of truth, if any, in such fundamentalistic assertions by some members of the profession as that due to physical, biological, and organizational circumstances, agriculture is unable to adjust supply to demand, and that it reacts perversely to prices.

The assertion that agriculture is denied a "just income" by being forced to operate in atomistic competition against monopolistic market power of industry, commerce, and labor is not supported by any conclusive evidence. To prove such causational relation calls for far more than demonstration of rigidities in "administered" prices or in certain wage rates of 17 million labor union members among a labor force of over 70 million people.

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[5] Theodore W. Schultz, "Value of U.S. Farm Surpluses to Underdeveloped Countries," Univ. of Chicago Off. of Agr. Econ. Res. Paper No. 6005, May 4, 1960, and *J. Farm Econ.*, 42:1019, Dec. 1960.

Cf. Edward S. Mason, "Foreign Money We Can't Spend," *Atlantic Monthly*, May 1960, pp. 7-8.

"Problem: How to Use U.S.-Owned Local Currencies," *Congressional Quarterly*, Weekly Rept. No. 25, June 17, 1960, pp. 1041-45.

It must not be overlooked that corporate income is an extremely unstable item in our economy and that unions have no control over the volume of employment or the payroll of industries and hence no control over the income of even a fully unionized vocational group. That unions have considerable power in collective bargaining over working conditions for their members is another matter.

The income and financial situation of the commercial farm operators, particularly when due consideration is given to the continual increase in their equity, give no cause for national alarm about an emergency or the urgency of sharply expanding public income support, but a great deal of cause for pondering a review of the means of policy.

Our agriculture is far from being left to hopeless isolation of millions of atomistically competing farmers who increase production when prices make production unprofitable. On the contrary, it is excellently organized with a farmer-owned and operated up-to-date long-, medium-, and short-term farm credit system, a tax-privileged, well-organized, vast cooperative system of nearly 10,000 marketing, farm-supply, and service enterprises with over 20 million members, $13.5 billion annual turnover, vast capital assets, and extraordinary bargaining power. About 100 of the largest farmer coops do annually over $20 million business each. Our agriculture is serviced by a government-supported land grant college system with agricultural research stations in every State of the Union and by a Federal-State financed up-to-date farm advisory system available free of charge to every farmer in every county of the U.S. All farm people, though most are self-employed, have the same benefits as urban employees under social security legislation.

Agriculture is a system of private, overwhelmingly family-operated enterprises, which in its 2 million commercial units behaves so remarkably businesslike that it gears production in accordance with the effective demand—a demand which for price-supported commodities includes the U.S. Government's unlimited commitment to buy any amount offered. The trouble is chiefly one of a lag in effective mobility of resources, particularly manpower, and of adjustments in land values.

Government price-income support policies have reduced the mobility of resources. Allotments and quotas have enhanced the land value. Rational economic adjustment may require use of some land at lower intensity (i.e., less manpower and purchased inputs per acre) in larger operational units. But this involves a certain relative reduction in land value and land taxes. The greatest rigidities that interfere with the mobility of resources are the result of price fixing in combination with allotments.

Arguments on behalf of the gradual restoration of a market economy for agriculture and a less costly, more effective system of farm policy are usually countered with the accusation that this implies laissez-faire and

an unfair denial of equal political subsidy treatment of agriculture, and with the absurd assertion that subsidies "built" the railroads, the airlines, and the maritime merchant fleets. Therefore, I want to stress that I do not believe in laissez-faire but in a strong government enforcing the rules of competition in a market economy and effectively promoting conditions favorable to economic growth and stability. The question cannot be whether the government should or should not use subsidies in dealing with the farm problem. The question is whether subsidies are being misused to make an economically untenable *status quo* socially bearable, or whether subsidies and intervention are self-liquidating and serve the purpose of keeping the farm economy basically free, self-adjusting, and capable of operating eventually without such aid. Subsidies are justifiable if they assist people in making adjustments and mitigate the hardships involved. The fast tax write-offs on farm equipment and storage facilities, freedom of all farmers from Federal tax on farm-used gasoline, and initially subsidized credit for rural electrification are also non-objectionable forms of subsidies.

However, to have the gross returns from all major farm products fixed and rationed among all farmers in a manner that is just or "fair to both consumers and producers" by the Congress, as some economists propose,[6] appears to me neither compatible with the institutional and legal frame of our economic system, nor feasible.

While it is theoretically not impossible to control the output of 4 million farms by comprehensive control of land and capital inputs, I hold it politically inconceivable that the American people, particularly the farmers, would ever accept the degree of regimentation and law enforcement that would be necessary to execute such control. It is moreover questionable whether the total costs involved for the nation would not by far exceed the exhorbitant ones of the present price stabilization. Compulsory supply controls immediately create by definition illegal units of supply, i.e., a black market. To make it effective such control would have to ration all purchased inputs, such as fuel, fertilizer, machinery. It makes no difference whether the "comprehensive supply control" would be exercised by the Government, or by compulsory farmer-operated commodity cartels, or whether quotas would be made negotiable. The assignment to all farmer cartels would be to restrain competition, administer shares in the market, and reduce the mobility of resources. This would lay waste in the realm of food, feed, and fiber production the main source of wealth in the American economy.

[6] Cf. Willard W. Cochrane, "Farm Technology, Foreign Surplus Disposal and Domestic Supply Control," *J. Farm Econ.,* Dec. 1959, pp. 885-99; *idem,* "Some Further Reflections on Supply Control," *ibidem,* Nov. 1959, pp. 697-717; *idem,* "The Case for Production Control Restated," in *Policy for Commercial Agriculture,* Joint Economic Com., 85th Cong., 1st Sess., Nov. 22, 1957, pp. 712-24.

If supply control should approach effectiveness, it would require extension to the industries which compete with farm production. Beyond that it seems fantastic to believe that in an integrated dynamic economy the conversion of a primary industry like agriculture into a politically directed state monopoly could stop there. Total cartelization of agriculture is only the beginning of total cartelization of the industries and trade. The historical precedent of this inescapable sequence under the Weimar Republic in Germany from 1928 to 1933 and its ominous finale under the Nazi regime, 1933-1945, should be sufficient deterrent to any repetition by contemporary eclecticists.[7]

Insofar as the results of a decade of extensive research by many of our most competent analysts on the supply function in agriculture are concerned, they have not gone beyond preliminary exploration and in my judgment do not provide any reliable quantitative knowledge with which a supply control system could be operated with any accuracy.[8]

The assumptions by some economists about the possibility of reducing aggregate output to market equilibrium by withdrawing enough crop acreage by expansion of the conservation reserve up to 60 or 80 million acres impress me as unwarranted and extremely expensive illusions. At best the conservation reserve provides additional opportunities for the retirement of elderly farm people chiefly on marginal units. There is no evidence in support of the idea that idling of acreage at public expense could become an effective decelerator of growth of aggregate output of agriculture.[9]

The unsatisfactory results of the present farm policy are almost exclusively the result of maladjusted legislation, not of administrative failure in its execution.

The overruling economic argument against a policy change toward effective lifting of farm income beyond the present level by supply restriction lies in the implied substantial jacking up of food and fiber prices to the consumer and the inevitable escalator effect on wages and prices. The cost-push inflation involved in it would tend to cause serious unemployment in export industries and deterioration of the balance of trade. Hence such policy would tend to imperil the exchange rate of the

[7] Cf. Karl Brandt, "The German Fat Plan and its Economic Setting," Food Res. Inst., Stanford Univ., 1938.

[8] Cf. the studies by William Addison, R. H. Allen, Louis H. Bean, Rex F. Daly, Karl A. Fox, Zvi Griliches, D. Gale Johnson, R. L. Kohls, George M. Kuznets, George W. Ladd, R. L. Mighell, Marc Nerlove, Don Paarlberg, T. W. Schultz, John R. Tedford, E. J. Working, and others.

Cf. particularly: Marc Nerlove and Kenneth L. Bachman, "The Analysis of Changes in Agricultural Supply: Problems and Approaches," *J. Farm Econ.*, 42: 531-54, Aug. 1960, and the appended bibliography of 80 items.

[9] Cf. Appendix B III, "Agriculture," in *Economic Report of the President, January 1960,* and particularly Appendix B II, "Agriculture," in *Economic Report of the President, January 1961.*

U.S. dollar. The savings in the Federal Budget by reduced CCC stocks would largely be lost in higher export subsidies.

## IV

The foregoing assumptions about the needs of economic policy in general and of agricultural legislation in particular lead me to suggest, for discussion and getting them tested within the economic profession for their economic validity as well as their practicability, guidelines for a possible alternative course in legislation for agricultural adjustment aid, that go in a different direction from those of fascism or the corporate state. There are quite a few proposals. Professor Hendrik S. Houthakker's "Transitional Acreage Payments" plan, which he abbreviates as TAP,[10] would bridge the gap between "artificially high" support prices and presumably lower prices riding in a free market over a transition period of five years. Payment per acre would be the same for all farmers, giving low-yield farmers proportionately more than under the present system. Professor Houthakker calls it a subsidy for past, but not for future inefficiency. He anticipates that acreage controls, government purchases, and export subsidies will become unnecessary and that the danger of increasing surpluses will disappear.

Professor Houthakker assumes that the "farm bloc's power" may vanish overnight. I do not believe that the assumed power of the farm bloc is what has kept legislation in the same tracks for 27 years. I believe the causes lie much deeper, namely, in what has so aptly been analyzed by J. S. Davis as agricultural fundamentalism. I would add to it that as an indestructible strand of a society's timeless memory all urban people have a fond affection for the farm, from which they or their forebears all came. It is the *Paradise Lost Complex* of modern metropolitan electorates that creates the phenomenon of increasing will to grant farm aid as the proportion of farm votes diminishes, a phenomenon typical of all industrial societies under representative forms of government.

Professor Boris C. Swerling has for several years worked out in great detail a Contributory Income-Insurance Plan for agriculture with initial Government contributions to the insurance fund.[11] The insurance would be tied to the individual, not to the farm. It would be social insurance with an upper limit of something like $5,000 per individual, based on income tax records. The plan disassociates farm legislation from commodity stabilization altogether, is compulsory, lets prices settle at a free market level.

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[10] Manuscript accepted by *The Review of Economics and Statistics,* to appear in issue of May 1961.

[11] While his research yielded chiefly staff papers for the Council of Economic Advisers till 1958, his ideas are condensed in the article "Income Protection for Farmers: A Possible Approach," *J. Pol. Econ.,* April 1959, pp. 173-86.

As a substitute for the price support policy the plan would, in my judgment, be unacceptable to the commercial farmers and their organizations and does not touch the question of what happens to the business of commercial agriculture and its gigantic investment within 4, 5, or 6 years.

I have already mentioned still another plan which envisages the correction of excess aggregate output by laying still 60 to 80 million acres of cropland by an increase of the conservation reserve. I consider this approach as a dead alley, unless productive acres, not whole farms, were fallowed under tight annual leases.

In view of the crucial need of a constructive alternative I put on the docket of our profession a course of legislation along the following lines:

A. Since the greatest maladjustment lies in the chronic underemployment of manpower in low-income farms, maximum assistance would be given by all competent Federal and State Government service agencies with particular emphasis on expansion of nonfarm employment.

B. The excess stocks of grain would be effectively eliminated from the U.S. and world grain markets by transferring title to a *Grain Conversion Board* under the statutory requirement that it cannot dispose of any of its stocks as grain but must convert all of them over a period of 6 to 8 years to staple livestock products and sell them exclusively in newly to be developed foreign markets and exclusively on the basis of long-term delivery contracts with food dispensing agencies abroad, particularly in new industrial areas of less developed countries where protein supplements to the diet are needed. These war-surplus disposal and market development transactions would be carried out by existing private enterprises and business firms. The Board would also be entitled to donate certain quantities to foreign charity. The high but limited cost of such disinvestment should be no deterrent vis-a-vis the absence of any constructive alternative and the extraordinary benefit of regaining a market free from the duress of the surpluses.

C. The Government would gradually (over a period of say four years) and progressively disengage itself from intervention in the commodity markets, thereby assist in the recuperation of their natural buoyancy in the absence of depressive surpluses, and it would simultaneously reprivatize the carrying of all visible stocks in first and second hand.

D. During this transitional period of disengagement the Government would financially assist producers of chronic surplus commodities in specified regions by buying from farmers, under specified contractual conditions, their allotments and marketing quotas, tapering the installment payments over the four years. One of the conditions would involve the farmer's commitments to fallow a specified percentage of his allotment acreage, with a tapering scale during the four years. Such massive finan-

cial aid would amount to indemnification for the abolition of unworkable means of farm policy adopted basically for war purposes and an institutional modification of the economy.

E. In order to get the Federal Budget expenditure for the farm program under control, the Congress would make a total appropriation for each fiscal year covering the expenditures involved in the indemnification, i.e., the purchase of the allotments.

F. The Government would give maximum support to agricultural exports by diplomatic efforts at removing discriminatory import restrictions abroad and by keeping U.S. markets open to foreign industrial products.

G. The Food-for-Peace Program would be continued.

This is a set of guidelines for a revision of agricultural legislation which I consider as one of several possible alternatives and which appears to me as an economically, socially, and politically constructive and feasible one. Legislation following these guidelines, properly administered, would adjust aggregate output via the market mechanism, without the fettering of farm enterprises or cartelization of industries, while protecting the economy against more inflation, and would shield the farmers against decline in their income and equity. Chiefly, such a program would create within a period of four years a situation in which the U.S. Treasury would no longer be mortgaged by, and the U.S. Government no longer be tied to, a continuation of anachronistic methods of farm policy. The precarious balance of payments situation makes a review of the Federal Budget item for agricultural price stabilization mandatory.

PARITY AND SUPPORT PRICES FOR FLUE-CURED TOBACCO*

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As OTHER writers have pointed out,[1] since the 1930's, tobacco states congressmen have been most successful in obtaining exceptional treatment for tobacco in farm parity and support price legislation. They have also been key leaders in the fight to retain the parity concept as a symbol of fairness to farmers and in the fight for rigid government price supports at a high percentage of parity. This paper describes and analyzes the historical and current developments in tobacco parity and support price legislation, with special reference to flue-cured tobacco.[2]

## *Parity and Support Prices, 1933-1940*

In the 1933 debate upon farm relief legislation in the closing session of the Seventy-second Congress, much time was devoted to fair exchange or parity prices for farm commodities. It seemed generally accepted in the Congress that the period August 1909-July 1914 should be used as a base period for computing such prices.[3] Suddenly, on January 12, 1933, Representative Marvin Jones, of Texas, introduced an amendment to a bill defining the fair exchange price for farm commodities as August 1909-July 1914 which stated, ". . . except that in the case of tobacco the base period shall be the period commencing September 1909, and terminating August 1919."[4] The principal justification given for this exception was that the average price of burley tobacco in the preceding twenty-five years had been much higher than in the period 1909-1914, and consequently that the 1909-1914 base period was not fair to tobacco.

No farm relief legislation was passed by the Seventy-second Congress, and the legislation first introduced in the House during the Seventy-third Congress reverted to a 1909-1914 base period for all commodities. The tobacco states congressmen shifted their position slightly and sharpened their arguments. It had been discovered that the use of the 1909-1919

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* This paper is published with the approval of the Director of Research, North Carolina Agricultural Experiment Station, as Paper 1199 of the Journal Series. Thanks are due B. G. Andrews, J. G. Maddox and W. L. Turner for their suggestions.

[1] John D. Black, *Parity, Parity, Parity,* the Harvard Commission on Research in the Social Sciences, Cambridge, Mass., 1942; Charles M. Hardin, "The Tobacco Program: Exception or Portent?" *J. Farm Econ.*, 28:920-37, Nov. 1946; B. U. Ratchford, "Federal Agricultural Policy in Relation to Tobacco," *J. of Politics,* 11:655-77, Nov. 1949; and Harold B. Rowe, *Tobacco Under the AAA,* the Brookings Institution, Washington, D.C., 1935.

[2] Parity and support price legislation has been identical for burley.

[3] *Cong. Rec.*, Vol. 76, esp. Jan. 5, 1933, pp. 1346-1354, and Jan. 6, 1933, pp. 1363-1393.

[4] *Ibid.*, Jan. 12, 1933, p. 1663.

base period for tobacco rather than 1909-1914 improved the parity price only slightly for cigarette tobacco, of which flue-cured is the most important single type.[5] Apparently for this reason, the 1909-1919 period was abandoned in favor of the period August 1919-July 1929. Defense of the more recent base was shifted to an argument that changes in the characteristics of and cost of production of tobacco made the 1909-1914 period inappropriate. The then Representative from Kentucky, Fred M. Vinson, argued this as follows:

> . . . Burley tobacco grown between 1909 and 1914 was an entirely different type of tobacco than that grown today. It was a heavier tobacco than the Burley grown in the past several years. . . . The lighter Burley was grown for cigarette purposes. The difference is as great as if it were a different type of tobacco. The average price for 1909-1914 is not a comparable price to the Burley that is grown today.
>
> Roughly speaking, 75 per cent of the tobacco grown today is used in cigarettes. Burley, flue-cured and Maryland types are the cigarette tobaccos. In 1915, 10 per cent of the tobacco grown was used for cigarette purposes. . . .[6]

The essence of this latter argument was that the 1909-1914 tobacco prices were not for tobacco similar to that in current production, and that, had they been, they would have been higher. Mordecai Ezekiel, Economic Adviser to the Secretary of Agriculture, gave credence to the argument when he suggested that legislation defining the fair exchange price for burley should give the Secretary of Agriculture discretion to choose a later base period if he found upon full investigation that the type of tobacco produced had changed materially.[7]

Apparently, Congress was impressed with the argument. The Agricultural Adjustment Act approved May 12, 1933, defined the base period for computing parity prices as follows: "The base period in the case of all agricultural commodities except tobacco shall be the pre-war period, August 1909-July 1914. In the case of tobacco, the base period shall be the post-war period, August 1919-July 1929."[8] This exception for tobacco raised the parity price for tobacco by 17 per cent above that using the 1909-1914 base period.[9]

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[5] *Ibid.*, Vol. 77, March 22, 1933, p. 746.

[6] *Ibid.*, p. 745.

[7] *Ibid.*, p. 745.

[8] *Agricultural Adjustment, A Report of Administration of the Agricultural Adjustment Act–May 1933 to Feb. 1934*, USDA, Washington, D.C., 1934, p. 361. The Senate passed an amendment which used the 1919-1929 base period for both dairy products and tobacco (*Cong. Rec.*, Vol. 77, April 10, 1933, p. 1434). The House refused to go along with the later base period for dairy products primarily because of the importance of dairy products as food and the effect of higher prices on the consumers. Dairy products were ultimately left on the original base period by Senate-House conferees.

[9] The market average price of flue-cured tobacco in the 1909-1914 base period has been estimated as 12.9 cents per pound (see Ratchford, *op. cit.*). The market

The 1919-1929 base period for computing parity prices for tobacco was used in all subsequent legislation through the Agricultural Act of 1938 and was retained through the 1940 crop year. It should be remembered that the parity price was of little value to producers of the major types of tobacco in the period 1933 through 1940, except in as far as it showed the tobacco farmers to be poorly off and provided ammunition for use in obtaining legislation designed to aid tobacco farmers through production restrictions, benefit payments and the like. Direct market price supports were not mandatory in this period, and price support operations were trivial up until 1939. Further, market price supports when applied were usually related to recent market prices rather than to the parity price. For this reason, it appears that the next victory by the tobacco states congressmen on the parity price front was a windfall gain rather than a planned coup.

### *Parity and Support Prices, 1941-1949*

In the first session of the Seventy-seventh Congress (1940), the tobacco states congressmen again proposed a change in the law increasing the parity price for burley and flue-cured tobacco by choosing the yet more recent base period of August 1934-July 1939. The same argument that had been so effective in 1933 was again used. That is, it was argued that the continuing change in the characteristics of tobacco produced in response to increased demand for cigarette tobaccos had increased production costs and made the earlier base period inappropriate. Representative Flannagan argued that, ". . . The increase in the production cost has been brought about largely by the increase in the tobacco now used for cigarettes."[10] This argument was bolstered by a letter from Secretary of Agriculture Wickard which stated in part, ". . . Since the changes which originally led to the use of the 1919-1929 base period for tobacco have been continuing in recent years, it now appears to be appropriate to adopt a later base period. . . ."[11] Edward A. O'Neal, President of the American Farm Bureau, also helped with a letter dated September 24, 1940, stating, ". . . farmers have shifted to the production of a thinner leafed tobacco which is more expensive to produce. This readjustment in the parity goal will help offset these increased production costs. . . ."[12]

Representative Flannagan added the argument that, in view of the war conditions in Europe, an increase in the parity price was necessary so that tobacco farmers might share in parity payments should prices

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average price in the 1919-1929 base period was 24.0 cents. When this price is divided by 1.59, the average Index of Prices Paid in the 1919-1929 period divided by 100, it yields an "adjusted base price" of 15.09 cents for the 1909-1914 period.

[10] *Cong. Rec.*, Vol. 86, Oct. 9, 1940, p. 13474.

[11] *Ibid.*, p. 13474.

[12] *Ibid.*, p. 13475.

drop sharply, thus protecting them against a disastrous drop in income. The heart of his argument is contained in the following statement:

> We find today that under the base period from 1919 to 1929, originally established in the AAA legislation, the parity is away below the cost price. We are only asking that we be given a more favorable period, the period from 1934 to 1939, so we will be able to participate in some of the benefit payments if our tobacco prices tumble.[13]

Although no factual information was introduced to support the arguments that changes to thinner tobacco had increased costs and made the change in base period reasonable, congressmen were apparently impressed. Representative Carlson of Kansas commented ". . . Statements already made indicate that the years selected under the original AAA were rather unfair to tobacco, therefore, I think this provision might well be adopted. . . ."[14] Congress followed this advice and amended the Agricultural Act of 1938 so as to redefine the base period for tobacco as August 1934-July 1939. The effect of this change was to raise the parity price for tobacco 22 per cent above that using the 1919-1929 base period and 43 per cent above that using the 1909-1914 base period.[15]

The 1934-1939 base period was used in computing parity prices for tobacco from 1941 through 1949. From 1941 through 1945, the principal advantages of the higher parity price to producers of the major types of tobacco were in the debate over OPA ceiling prices and in the establishment of prices at which the Commodity Credit Corporation bought for lend-lease and foreign sales. For crop years 1946 through 1949, however, mandatory support prices at 90 per cent of parity were effective for both burley and flue-cured, and the higher parity price did increase market prices. These higher market prices became an important item in the later development of parity prices under the Agricultural Act of 1949.

### *Parity and Support Prices, 1950-1959*

During and immediately following World War II, parity prices for farm commodities came to have new significance. Rather than being permitted to work toward achieving parity prices in the market through production restrictions, storage programs, disposal operations, etc., the Secretary of Agriculture was required by law to maintain the market price for many farm products at specified percentages of parity, and surpluses began to develop in the post-war years.

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[13] *Ibid.*, p. 13474.

[14] *Ibid.*, p. 13476.

[15] The market average price in the 1934-1939 base period was 22.9 cents per pound. When this price is divided by 1.24, the average Index of Prices Paid in the 1934-1939 period divided by 100, it yields an "adjusted base price" of 18.47 cents for the 1909-1914 period.

As a result of the developing surpluses, the method of computing parity and support prices came under debate in the Congress in the spring and summer of 1948. It was generally agreed that some revision in the method of parity price computation was needed so as to reflect changes over time in relative costs of producing farm products since the 1909-1914 period. At the same time, many people believed that, for farm prices as a whole, the 1909-1914 base period should be retained. It was felt that changes in production costs generally would be reflected in market prices for the different farm commodities, since prices tend to equal costs of production in a competitive market. Therefore, legislation was introduced providing for a modernized method of computing parity price which retained the 1909-1914 base period but reflected changes over time in relative prices of farm commodities.

Another part of the congressional debate centered on flexible versus rigid price supports. The Aiken Bill passed by the Senate called for both modernized parity and flexible price supports. Prices at which basic commodities were to be supported varied inversely with supply from 60 to 90 per cent of parity.

Tobacco states congressmen initially opposed modernized parity and were part of a group which opposed the flexible price support provisions. Representative Chapman (Kentucky) stated:

> The Agricultural Adjustment Act of 1938 as amended was the basis of our national farm program. Its operation in the field of tobacco has proved to be the most successful and beneficial farm program in the history of the country. The fixed base period for computation of parity has been tried and proved successful. Ninety per cent of parity as the support price of burley and flue-cured tobacco has successfully met the test of experience.[16]

Opposition to use of modernized parity for tobacco abated, but the tobacco states congressmen continued to oppose flexible price supports. Senators Barkley and Cooper (Kentucky) offered an amendment on June 17, 1948, to exempt tobacco from the flexible provisions of the Aiken Bill and to keep supports at 90 per cent of parity when marketing quotas were in effect.[17] The argument for giving special treatment to tobacco was based primarily on the contention that growers faced monopsonistic conditions in the markets. It was also contended that tobacco was not storable on farms and, therefore, was a special case.[18] This amendment provoked considerable debate but finally passed by one vote, 41-40. The Aiken Bill was eventually altered in conference so as to keep rigid supports for one additional year and start flexible supports in 1950. However, the 90 per cent parity provision for tobacco stayed in the final bill.

[16] *Cong. Rec.*, Vol. 94, June 11, 1948, p. 7904.
[17] *Ibid.*, June 17, 1948, p. 8537.
[18] *Ibid.*, pp. 8537-8540.

In 1949, the farm policy debate on rigid versus flexible price supports continued, but a modified flexible price support provision was contained in the 1949 Act. However, tobacco maintained its position as a special case throughout the long arguments. Tobacco states congressmen apparently were happy with tobacco's position, and other congressmen did not see fit to reconsider the favored treatment for tobacco.

The Agricultural Act of 1949 included a provision to add wages in computing the Index of Prices Paid. This provision raised parity prices about 5 to 6 per cent and increased the parity price for flue-cured from 42.8 cents per pound, as it would have been under the 1948 Act, to 45.3 cents.

Modernized parity was first used for tobacco in 1950. Changes over time in tobacco prices relative to other farm prices were reflected in modernized parity through use of an adjusted base price, calculated by dividing the average price in the preceding 10 years by the average Index of Prices Received in the preceding 10 years and multiplying by 100. The parity price is calculated by multiplying the adjusted base price by the June 15 Index of Prices Paid[19] (including wages, interest and taxes) and dividing by 100.[20]

### *The Price Stabilization Debate*

Modernized parity was generally acceptable to the tobacco industry from 1950-1957. It gave a slightly higher parity price than that which would have been used had the 1934-1939 base period and the old method of computing parity been in effect, but the differential was slight (Table 1).

Beginning in 1958, however, the factors affecting the adjusted base price began to cause modernized parity to rise much more rapidly than the Parity Index. Tobacco prices were supported at 90 per cent of parity, while the support level on most other farm commodities was lowered. Prices of nonsupported commodities also tended generally downward from the high level of 1951 and 1952. In computing the 1958 parity price, for example, the 1957 Index of Prices Received of 242 replaced the 1947 Index of 276 in the 10-year moving average; the 1957 tobacco price of 55.4 cents replaced the 41.2 cents of 1947 in the 10-year moving average

[19] An earlier parity price estimate was usually made before March 31, using the most recent monthly Index of Prices Paid. If this gave a higher parity price than that calculated using the June 15 Index, the earlier parity price was used in determining the support price.

[20] Modernized parity prices for tobacco are computed using the Index of Prices Paid, including interest, taxes, and wages. This index is referred to hereafter as the Parity Index. Old parity prices for tobacco are computed using the Index of Prices Paid, excluding interest, taxes and wages. This index is referred to as the Index of Prices Paid.

TABLE 1. FLUE-CURED TOBACCO SUPPORT PRICES UNDER ALTERNATIVE PARITY CALCULATIONS, FLUE-CURED TOBACCO PRICES AND INDEXES OF PRICES RECEIVED AND PRICES PAID, 1946–1959

| Year | Index of Prices Paid as of June 15 | | Index of Prices Received[a] | Season average tobacco price[b] | Alternative support prices at 90 per cent of parity[c] | | | |
|---|---|---|---|---|---|---|---|---|
| | Unrevised and excluding taxes, interest and wages[a] | Revised and including taxes, interest and wages[a] | | | 1909–1914 base period | 1919–1929 base period | 1934–1939 base period | Modernized parity |
| | | | | | *Cents per pound* | | | |
| 1946 | 194 | 203 | 236 | 48.3 | 22.5 | 26.3 | *32.2* | — |
| 1947 | 242 | 238 | 276 | 41.2 | 28.1 | 32.9 | *40.2* | — |
| 1948 | 264 | 263 | 287 | 49.6 | 30.7 | 35.9 | *43.9* | — |
| 1949 | 255 | 253 | 250 | 47.2 | 29.6 | 34.6 | *42.4* | — |
| 1950 | 260 | 255 | 258 | 54.7 | 30.2 | 35.3 | 43.2 | *45.0* |
| 1951 | 286 | 283 | 302 | 52.4 | 33.2 | 38.8 | 47.5 | *50.7* |
| 1952 | 288 | 288 | 288 | 50.3 | 33.4 | 39.1 | 47.9 | *50.6* |
| 1953 | 283 | 277 | 258 | 52.8 | 32.9 | 38.4 | 47.0 | *47.9* |
| 1954 | 286 | 282 | 249 | 52.7 | 33.2 | 38.8 | 47.5 | *47.9* |
| 1955 | 286 | 282 | 236 | 52.7 | 33.2 | 38.8 | 47.5 | *48.3* |
| 1956 | 289 | 286 | 235 | 51.5 | 33.6 | 39.2 | 48.0 | *48.9* |
| 1957 | 299 | 296 | 242 | 55.4 | 34.7 | 40.6 | 49.7 | *50.8* |
| 1958 | 304 | 305 | 255 | 58.2 | 35.3 | 41.3 | 50.5 | *54.6* |
| 1959 | 306 | 310[d] | 248[d] | 58.2 | 35.5 | 41.6 | 50.9 | *57.2*[e] |

[a] Taken from contemporary issues of *Agricultural Prices*.
[b] Taken from USDA, AMS, *Annual Report on Tobacco Statistics, 1953*, Dec. 1953, p. 9, and *Tobacco Situation*, March 1960, p. 35.
[c] The italicized price is the one which was in effect. Modernized parity is computed using the revised Index of Prices Paid, including taxes, interest and wages; the others are computed using the unrevised Index of Prices Paid, excluding interest, taxes and wages.
[d] Estimated.
[e] The support price was 55.5 cents due to the 1959 revision in the Parity Index and the Index of Prices Received.

of tobacco prices (Table 1). The modernized parity formula had put tobacco parity prices on an escalator. As a result of the modernized formula and the holding of tobacco supports at 90 per cent of parity while permitting downward adjustments in other support prices, tobacco parity would rise automatically—even with no increase in the Parity Index. Of the 3.8 cents rise in the support price in 1958, about 1.6 cents was due to the increased Parity Index. But about 1.5 cents was due to the higher 10-year average tobacco price and .7 cent to the lower 10-year average Index of Prices Received.

Again in 1959, the flue-cured support price would have gone up 2.6 cents (of which 1.7 cents was due to changes in the average tobacco price and the Index of Prices Received), but a revision in weights for calculating the Parity Index and the Prices Received Index[21] put the sup-

[21] B. R. Stauber, R. F. Hale and B. S. Peterson, "The January 1959 Revision of the Price Indexes," *Agr. Econ. Res.*, 11:33-80, April-July 1959. This weight revision changed the June 15, 1959, Parity Index from 310 to 298 and the 1959 Index of Prices Received from 248 to 243.

port price at 55.5 cents, rather than the 57.2 cents which would have been in effect without the weight revision.

Table 2 illustrates the escalator effect of modernized parity for flue-cured tobacco support prices. Modernized parity support prices are estimated through 1965 assuming no change in the Parity Index, making it possible to see the escalator effect directly. Using the Index of Prices Paid for June 15, 1959, of 306,[22] estimated support prices (90 per cent of parity) are 35.5 cents with the 1909-1914 base, 41.6 cents with the 1919-1929 base and 50.9 cents with the 1934-1939 base. With no change in the Parity Index and the Index of Prices Paid, these support prices would not change.

A Parity Index of 298 (reflecting the 1959 weight revision) is used for the modernized parity computations of Table 2. It is also assumed that the Index of Prices Received would be 245 (compared with the revised figure of 243 for 1959) for 1960 on. Further, it is assumed that the market price for flue-cured tobacco would average 2 cents per pound above the support level.[23] If the differential should be greater than 2 cents, the modernized parity price would rise still more rapidly than the estimates in Table 2.

The 10-year moving averages in Table 2 show average tobacco price rising and the average Index of Prices Received falling throughout the whole period of 1959-1965. Both of these factors operate in the same direction; i.e., they cause the adjusted base price and, therefore, the support price to rise. Without any increase in the Parity Index, the projected flue-cured tobacco support price is more than 65 cents by 1965. Furthermore, the differential between support price computed by the method used prior to 1950 (using the 1934-1939 base period) and modernized parity support price would increase from less than 5 cents in 1959 to more than 14 cents in 1965.[24]

The sharp rise in support prices for flue-cured tobacco in 1958 caused considerable concern in the tobacco industry. The United States' share of world flue-cured exports had been falling for some years, and foreign

[22] The unrevised Index of Prices Paid is used for computing old parity, and it was not revised in 1959.

[23] Each tobacco grade is supported at a price which should give farmers 90 per cent of parity for a crop with a normal grade distribution. In order to buy tobacco, buyers must bid above the support level for each grade. Thus, the price for flue-cured tobacco effectively is supported at something above 90 per cent of parity. The only way that the season average price can be below the support level is to have an abnormally poor grade distribution. The estimate of 2 cents above support seems conservative in light of the average differential of 3.9 cents per pound in 1950-1959 (Table 1).

[24] If the Index of Prices Paid and the Parity Index rise, all support prices in Table 2 would tend to be increased proportionately. The absolute differences between old parity support and modernized parity support would increase.

TABLE 2. ESTIMATED SUPPORT PRICES FOR FLUE-CURED TOBACCO WITH NO CHANGE IN THE INDEXES OF PRICES PAID UNDER ALTERNATIVE PARITY CALCULATIONS AND 10-YEAR MOVING AVERAGES USED IN MODERNIZED PARITY CALCULATIONS, 1959–1965

| Year | Old parity[a] | | | Modernized parity[b] | 10-yr. moving averages | |
|---|---|---|---|---|---|---|
| | 1909–1914 base period | 1919–1929 base period | 1934–1939 base period | | Tobacco price[c] | Index of Prices Received[d] |
| | *Cents per pound* | | | | | |
| 1959 | 35.5 | 41.6 | 50.9 | 55.5 | 52.8 | 255 |
| 1960 | 35.5 | 41.6 | 50.9 | 56.9 | 53.9 | 254 |
| 1961 | 35.5 | 41.6 | 50.9 | 57.7 | 54.3 | 253 |
| 1962 | 35.5 | 41.6 | 50.9 | 59.8 | 55.0 | 247 |
| 1963 | 35.5 | 41.6 | 50.9 | 62.2 | 56.2 | 243 |
| 1964 | 35.5 | 41.6 | 50.9 | 63.6 | 57.3 | 242 |
| 1965 | 35.5 | 41.6 | 50.9 | 65.2 | 58.6 | 242 |

[a] An Index of Prices Paid (unrevised and excluding taxes, wages and interest) of 306 was used.
[b] A revised (including taxes, wages and interest) Index of Prices Paid of 298 was used. This compares with 310 before the 1959 weight revision.
[c] It was assumed that the market price would average 2 cents per pound above the support price.
[d] An Index of Prices Received of 243 was used for 1959 and 245 was used for succeeding years. The 243 compares with 248 before the 1959 weight revision.

buyers indicated that price was a large factor causing them to shift their purchases to other countries. These foreign buyers wanted assurances that the escalator type of price rise would be halted. Joe R. Williams of the Tobacco Division, USDA, reflected the industry's concern with rising prices in his statement that: ". . . unless some way is found to meet his [the foreign buyer's] price problem the U. S. will lose its export trade at the rate of 2-3 per cent a year, with the exception of a quality market where price is not an important factor."[25] Williams made projections showing the expected rise in future flue-cured tobacco prices[26] and also pointed out that the high price of flue-cured tobacco was providing an incentive for domestic companies to increase use of homogenized leaf and filter cigarettes.

### *The 1959 debate*

Congressmen from the tobacco states brought the industry's views before the Congress in 1959. Senator Jordan (North Carolina) made the industry's case as follows:

For the past year growers, warehousemen, manufacturers, exporters, and others interested in tobacco have been concerned over steady increases in prices

[25] Joe R. Williams, "The American Tobacco Grower is at the Cross-Roads," *Tobacco*, Vol. 147, No. 15, October 10, 1958, p. 11.
[26] *Ibid.*

which have resulted from the use of modernized parity in computing price supports.

For some time it has been obvious that important export markets will be seriously endangered unless tobacco prices are stabilized.

As a result of the impending danger to exports, a group of leaders in the tobacco industry began a series of meetings last fall in an effort to work out a sound and reasonable solution to the problem.

It was a matter of stabilizing prices and regaining export markets, or of taking a sharp reduction in acreage.[27]

A bill, H.R. 5058, to stabilize tobacco support prices was introduced in the House of Representatives by Representative Jennings (Virginia) in January 1959. After hearings, this bill was slightly modified and, as amended, was identical to S. 1901, introduced by Senators Cooper (Kentucky) and Jordan (North Carolina). Senator Jordan stated:

> The effect of S. 1901 is simple. It provides that there shall be no increase in the dollars and cents level of price supports on most types of tobacco above the 1958 price support level until price support computed under old parity exceeds the 1958 dollars and cents level. It further provides that in the event the price support under old parity exceeds 1958 supports, then the Secretary shall choose between old parity or new parity in setting price supports, whichever is lower.[28]

This meant that flue-cured tobacco would be supported at 54.6 cents until old parity rose to this level. In addition, the bill provided that old parity for tobacco would now be computed using the revised Index of Prices Paid, including interest, taxes and wages. This revision reduced 90 per cent of old parity price for flue-cured tobacco in 1959 from 50.9 cents (see Table 1) to 49.0 cents.[29] Thus, the Parity Index would have had to rise by more than 11 per cent before old parity would become effective.

The Eisenhower Administration opposed the bill.[30] In general, the Administration felt that the bill was objectionable because it froze supports at a high level, brought back into use a formula which had been discarded previously and had too old a base period, gave a dual standard of parity prices and continued to place tobacco growers at an advantage over other growers in that it was the only crop for which the Secretary had no discretion in setting support levels.

The Administration obviously was in the position of favoring the bill

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[27] *Cong. Rec.*, Vol. 105, May 21, 1959, p. 7863.

[28] *Ibid.*, p. 7864.

[29] The revision yielded an "adjusted base price" of 18.32 cents rather than 18.47 cents for the 1934-1939 period (see footnote 15). In addition, the Parity Index was 298 on June 15, 1959, while the unrevised Index of Prices Paid was 306. The bill also provided for modernized parity to be used if it were less than old parity. However, this possibility is too remote to consider.

[30] The position of the Administration was stated in a letter from True D. Morse, Acting Secretary, to Senator Ellender, Chairman of the Senate Committee on Agriculture and Forestry. *Cong. Rec.*, Vol. 105, May 21, 1959, p. 7864.

in the sense that it would stop the rapid rise in tobacco support prices. Yet, the Administration wanted to get away from the parity concept and give more authority to the Secretary.[31] In line with the Secretary's position that the bill did not go far enough, the President vetoed the bill after it passed both houses. The President stated the Administration's reasons for the veto as follows:

> The bill's merits are few. For the first time in many years tobacco prices would be supported at less than 90 per cent of parity—in the first year, for example, at 88 per cent for flue-cured tobacco and at 87 per cent for burley. Supporting tobacco prices as provided in S. 1901, rather than at 90 per cent of parity under a continuation of present law, would result in a saving to the U.S. Government in the first year of $14 million.
>
> The bill's demerits, however, are fundamental and far reaching. The bill takes a long step backward by resurrecting 90 per cent of "old parity" as one basis for determining the support level for tobacco. . . .
>
> But more importantly, I cannot approve a bill that holds out hope to the tobacco farmer that it will help him solve his problems, when such is not the case. . . . The deterioration in our tobacco sales abroad can be directly attributed to the high level of price supports that are required by existing law. . . . The best that can be said about S. 1901 is that it might slow down the rate at which we are losing our fair share of foreign markets. It would not prevent further losses. It certainly will not regain any lost markets, because the level of price supports it requires would still be too high.
>
> I believe the bill's demerits far outweigh its merits, and accordingly I am returning it without my approval.[32]

Thus, in 1959, tobacco prices were again supported at 90 per cent of modernized parity and rose to 55.5 cents (Table 2).[33]

### *The 1960 debate*

In 1960, several identical bills to stabilize tobacco support prices were introduced in the House, while Senator Jordan introduced a companion bill for himself and seven other Senators in the Senate. These bills provided for a freeze in support for 1960 at the 1959 level of 55.5 cents. Starting in 1961, the support price would be the 1959 support divided by the 1959 Parity Index multiplied by the average of the Parity Indexes for the three previous years. The House bill, H.R. 9664, introduced by Watt Abbit (Virginia), passed both houses with little opposition and was signed into law by the President.

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[31] It should be pointed out that the bill did depart from the parity concept in that it froze prices for a period of time. Congressman Quie (Minnesota) stated, "Mr. Chairman, regarding this bill, I think it is important to keep in mind the fact that it provides a clear recognition that parity, and the parity formula, is no sacred cow—and that we need not depend entirely on parity formulas." *Ibid.*, June 10, 1959, p. 9343.

[32] *Ibid.*, June 25, 1959, p. 10876.

[33] As previously noted, it would have risen to 57.2 cents but for the January 1959 revision of weights.

Certain changes in position were evident in 1960. The American Farm Bureau Federation, which had opposed the 1959 bill, supported the 1960 bill. The Administration, too, altered its stand. Secretary Benson stated in a letter to Senator Ellender:

> This bill is primarily a recognition by all industry leaders of the deleterious effects on the tobacco producers of the constant increases in support prices under the operation of the present program. While this bill does not go as far as we would like, it is a step in the right direction.[34]

The method of calculating support prices in the 1960 bill apparently made the bill more palatable for some foes of rigid supports. Congressman Dague (Pennsylvania) stated:

> Mr. Chairman, as a member of the Committee on Agriculture for more than 13 years, I have consistently opposed the rigid high support 90 per cent of parity price-fixing concept. . . . I am supporting H.R. 9664, the bill now before us, because it is a step away from rigid 90 per cent of parity price supports for tobacco, a program many of us have considered unwise for some time.[35]

Congressman Hoeven (Iowa), who had attempted to amend the 1959 bill to include a 2-year freeze on supports until a better method of determining support levels could be determined, also found the 1960 version to his liking. He said, ". . . this bill stands as recognition of the fact that 90 per cent of modernized parity for tobacco is unsound and should be corrected. . . ."[36]

*The 1959 Bill and the 1960 Act compared*

Under the 1960 Act, a first step in one method of computing the support price in years after 1960 is to divide the 1959 support price (which is 90 per cent of the 1959 parity price) by the 1959 Parity Index (divided by 100). This statistic is 55.5/2.98, or 18.62, which we call the *adjusted base support price* for the 1960 Act. The support price is the *adjusted base support price* multiplied by the average Parity Index (divided by 100) for the preceding three years.

A comparable procedure for computing the support price under the 1959 Bill is to multiply the adjusted base price for the 1934-1939 period[37] by .9 to obtain the *adjusted base support price* under the 1959 bill. This is 18.32 times .9, or 16.49. The support price would have been 16.49 cents multiplied by the June 15 Parity Index (divided by 100) or 54.6 cents, whichever is greater.

[34] *Cong. Rec.*, Vol. 106, February 15, 1960, p. 2252.
[35] *Ibid.*, Feb. 9, 1960, p. 2160.
[36] *Ibid.*, p. 2164.
[37] See footnote 29.

Assuming a continuing rise in the Index of Prices Paid,[38] the method of computing support prices under the 1959 bill would have become effective when the Parity Index rose to 332 ($3.32 \times 16.49 = 54.7$ cents). At that time, and assuming that the three-year average Parity Index will lag ten points behind the current Index, the support price under the 1960 Act will be 60.0 cents ($18.62 \times 3.22$), 5.3 cents or approximately 10 per cent higher than would have been the case with the 1959 bill. If the Parity Index should stabilize at a level of 332 or higher, the differential would gradually rise to approximately 13 per cent. A falling Index, from a level above 332, would increase the differential still further.

### *Summary*

Tobacco states congressmen generally have obtained relatively favorable parity and price support legislation for flue-cured tobacco. The Agricultural Adjustment Act of 1933 used the 1919-1929 base period instead of the 1909-1914 base period for tobacco, thereby increasing flue-cured parity prices about 17 per cent. In 1938, the base period for tobacco was changed to 1934-1939, increasing the tobacco parity price 22 per cent above that using the 1919-1929 base period. In 1948 and 1949, tobacco states congressmen were able to obtain price support legislation keeping tobacco supports at 90 per cent of parity, while other commodities were supported at flexible levels, inversely related to supply.

The modernized parity formula adopted in the 1948 and 1949 legislation caused tobacco parity prices to increase sharply in 1958 and seemed certain to cause a rapid rise in the future. This brought about concern in the tobacco industry that United States tobacco might be priced out of the foreign markets, and representatives of the tobacco industry asked for legislation to stabilize prices. Such legislation was introduced in 1959 and again in 1960. It is apparent from the debates of 1959 and 1960 that the Administration and the tobacco industry were both in favor of halting the rapid rise in tobacco supports to help preserve the export market. President Eisenhower vetoed the 1959 bill to stabilize supports because, among other reasons, it returned to the old parity concept and did not reduce prices enough. The method of computing supports was altered slightly in 1960, and the President signed the bill. But in so doing, the Administration settled for a method of computing support prices that will eventually lead to flue-cured support prices about 10 to 13 per cent higher than would have occurred under the 1959 bill which the President vetoed.

The 1960 Act does provide for lower and more stable support prices than under modernized parity. For example, should the Parity Index

[38] This appears to be the most reasonable of alternative assumptions.

rise to 332 by 1965, the support price would be about 74.5 cents with modernized parity, if the other assumptions in Table 2 are correct. The 1960 Act would give a support of 60.0 cents for a three-year moving average Parity Index of 322, about 14.5 cents or 19 per cent less than for modernized parity by 1965. It is clear that the 1960 Act is a step in the direction of more stable, lower flue-cured prices. But if lower support prices, as requested by the flue-cured industry, are needed to maintain or expand exports, it appears that the stubborn position taken by the Administration in 1959 in not accepting the bill because of its return to the old parity standard was ill-advised. The 1960 Act provides for a support price which is determined by a parity formula just as surely as the 1959 bill; it is just a different form of parity.

# OPTIMUM SUPER MARKET CHECK-OUT FACILITIES: AN APPLICATION OF QUEUING THEORY[1]

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DURING the past decade queuing theory has established itself as a welcome addition to the ever expanding repertoire of those who practice operations research. It provides a theoretical basis for formulating a model in order to predict the behavior of a system that attempts to provide services for randomly arising demands. Its applications have been many and varied. For instance, it has been applied to telephone trunking operations, inventory control and traffic control at toll booths.[2] These represent only a small sample, but they serve to point out that queuing theory is sufficiently flexible to be applicable to a variety of problems involving flow of "customers."[3]

The purpose of this paper is to delineate a queuing model used for an analysis of super market check-out operation. First, a general discussion of the nature of a queuing problem is given. It is followed by a statement of the problem considered in this study and some solutions to the problems are proposed. Finally some empirical results of applying the procedures suggested here to one of the nationally known chain food stores in Detroit are presented for illustration. In the appendix, some results of statistical analysis pertaining to probability distributions of customer arrivals and of service times are discussed.

This paper is chiefly concerned with mathematical determination of optimum check-out facilities under certain given conditions. As such, institutional and managerial arrangements necessary for implementing the mathematical solutions proposed in the following pages are not discussed.

### *What Is a Queuing Problem?*

There are many operational problems involving flow of customers in which the following two conditions can be observed:

(1) Units that require service sometimes wait for their turn because there is a shortage of service facilities.

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[1] This paper is based on a study which was carried out while the author was a graduate assistant at the Department of Agricultural Economics, Michigan State University. The author is indebted to the reviewers for their valuable comments and suggestions.

[2] Molina, E. C., "Application of the Theory of Probability to Telephone Trunking Business," *Bell System Tech. J.*, 6:461–94; Flagle, C. D., "Queuing Theory and Cost Concepts Applied to a Problem in Inventory Control," *Operations Research for Management*, Vol. II, Baltimore, Johns Hopkins Press, pp. 160–77; Edie, L. C., "Traffic Delays at Toll Booths," *J. Operations Res. Soc. Amer.*, Vol. 2.

[3] In queuing theory, the term "customer" is not restricted to a person. It can mean an incoming telephone call to a central switch-board or an automobile waiting to pass through a toll gate.

(2) The servicing facilities sometimes remain unused, not only because of the lack of customers in quantity, but also because of the nature of the time spacing between customer arrivals.

The first of these conditions would result in the formation of a waiting line of customers. The second condition can be thought of, by analogy, as involving a queue of idle service facilities. The shortage and surplus of service facilities are due to the difficulty, if not impossibility, of anticipating the amount of facilities required, because of random elements which influence demand for service both in time and quantity.

Under these conditions, a "queuing problem" arises. The problem is to adjust the amount of service facilities or the behavior of arriving units in order that the queuing process can be operated in as efficient and economical a manner as possible. The relevant cost functions for a queuing process consisting of a queue of input units are shown in the graph in Fig. 1. The total variable cost (*TVC*) per unit time of operating a system which generates a queuing process is made up of operating cost (*OC*) and waiting time cost (*WTC*).

Waiting time cost is defined as the cost of losing a potential customer

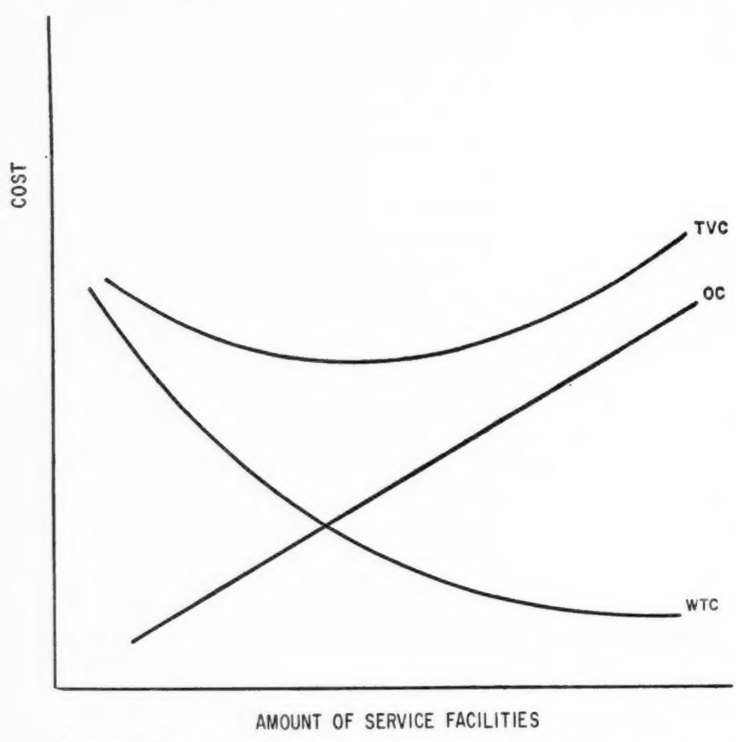


FIGURE 1. TOTAL VARIABLE COST OF OPERATING A QUEUING PROCESS.

because of insufficient service facilities. In general, operating cost may be assumed to increase in proportion to the amount of service facilities provided. On the other hand, waiting time cost probably decreases at a decreasing rate as more service facilities are added to the system.

Since the *TVC* function cannot be specified with a high degree of certainty due to the stochastic nature of customer arrivals, it becomes desirable to incorporate the notion of probability into the *TVC* function. Queuing theory has proved to be useful for this purpose. It provides a logical means of determining the relationships among the flow of arriving units, amount of service facilities, and quantities such as the average waiting time and average queue length which can be used to measure grade of service. When these relationships are known, the amount of service facilities required for the desired standard of service can be determined in advance to satisfy certain criteria of optimum.

Queuing theory can be applied in two different ways. These are usually referred to as the mathematical (or analytical) and simulated sampling approaches.

The mathematical approach begins with specifications of probability distributions regarding customer arrivals and service times. Based on these specifications, relationships that describe the queuing process are derived by writing down statements about the probability of there being a given number of customers waiting in line under various conditions. These relationships can be solved for such quantities of interest as average number of customers in the system and expected length of waiting lines. By combining these quantities with the information regarding cost, one can analytically arrive at the conditions under which a minimum cost is attainable.

Mathematical solution of the problem is neat. However, sometimes the nature of probability distributions of customer arrivals and service times is such that it is very difficult to obtain the quantities of interest (average number of customers in the system, average queue length, etc.,) in the form of reasonably manageable mathematical formulae.

If this is the case, an alternative procedure is the simulated sampling approach. For this approach, a technique known as the Monte Carlo method is commonly used. This is done by first establishing the pattern of events from limited observations. Then by the use of a table of random numbers, statistics on arrivals and service times are duplicated on a high-speed electronic computer, and sampling properties of these statistics are obtained. This approach has become more useful as a result of recent development in high-speed computers.[4]

[4] An example of studies which made use of the simulated sampling approach is Cox et al., "Application of Queuing Theory in Determining Livestock Unloading Facilities," *J. Farm Econ.*, Feb. 1958.

*Statement of the Problem*

From the foregoing discussion, it appears that the check-out service provided by a super market has all the necessary features that make up a typical queuing problem. There are customers who demand service; as each customer reaches a service channel, he receives a service. After a certain service time, he leaves. If the service channel is not immediately available to him he joins a queue. In most cases, the management has little control over the arrivals of customers to the check-out area either in quantity or in time; it can, however, expand or contract facilities to meet a certain prespecified optimum criterion. The problem involves a balancing of the cost incurred by providing a certain amount of check-out facilities for a given period of time against the cost of losing customers in the future because of inferior service standards.

*Specifications of the Queuing Model*

Various queuing models can be constructed by altering specifications in regard to: (1) the number of service points, (2) probability distributions of customer arrivals and service times, (3) queue discipline, and (4) queue length.

The queuing model considered here consists of multiple exponential channels with a Poisson input, infinite queue and strict queue discipline. Multiple exponential channels means that there are more than one service point and the time needed for a customer to be served at a service point follows a negative exponential distribution. Poisson input refers to the assumption that the number of arriving customers per unit time is a Poisson variate. Infinite queue refers to situations in which every arriving customer must join the queue no matter how long it happens to be. Strict queue discipline is the so-called "first come first served" rule. These specifications are delineated in more detail in the remainder of this section.

This model is applicable to the check-out operation with more than one stand. These check-out stands are assumed to have identical service mechanisms and each of them can operate independently of the others. Furthermore, it is assumed that each stand can be operated at two different levels of average check-out rate, $\mu_1$ and $\mu_2$. In the present study, $\mu_1$ is the rate for stands operated by a checker alone, $\mu_2$ the rate when the checker is assisted by a package boy. Suppose there are $m-k$ check-out stands with the average service rate of $\mu_1$ and $k$ check-out stands which have the average service rate of $\mu_2$; then each of $m$ check-out stands has the average service rate, $\mu$,

$$\mu = \frac{(m-k)\mu_1 + k\mu_2}{m}, \tag{1}$$

This scheme permits reducing the problem to the simple case of $m$ equivalent service channels.

In the course of analysis the number of check-out stands to be made available to customers at any given time will be less than or equal to the number of stands which exists at the outset of analysis.

Customers are considered to arrive at the check-out area at a certain average rate, $\lambda$. As soon as each customer arrives at the check-out area, he moves into any check-out lane which is free to service him. If he finds all the lanes occupied, he will join a hypothetical common queue. Under these conditions a waiting line exists when the number of customers in the check-out area exceeds the number of operating check-out stands at any given time, and their difference is by definition the length of waiting line.

The main feature of any queuing model rests in its characterization of the input process and capacity of service mechanism in terms of probability distributions. Here it is postulated that the customers arrive at "random," i.e., the number of arrivals per unit time is a Poisson variate. From this assumption, it follows that the time intervals between successive customer arrivals have independent and identical negative exponential distributions.[5] In symbols, the probability that there will be exactly $n$ arrivals in a time interval $t$ is

$$P_n(t) = \frac{(\lambda t)^n}{n!} e^{-\lambda t}. \tag{2}$$

This implies that the probability distribution of the interarrival times of customers is

$$P(t) = \lambda e^{-\lambda t}. \tag{3}$$

As to the service time, i.e., the time necessary for a particular customer to go through an average check-out stand, the assumption is that successive service times are statistically independent and each is exponentially distributed. In symbols

$$P(t) = \mu e^{-\mu t}. \tag{4}$$

### *Expected Values of Various Quantities of Practical Interest*

After the fluctuations of customer arrivals and service times have been specified in terms of probabilities, other measurable quantities associated with the check-out operation can be considered as stochastic variables which vary with time about some average values. There are two possible ways of studying these stochastic variables. The first deals with the steady state or stationary phenomena of the variables. The main purpose of this first approach is to determine how the variables behave in the long run. The second approach has to do with the transient behavior of the variables, i.e., the behavior of the stochastic variables as a function of time.

[5] A proof of this statement can be found in W. Feller, *Introduction to Probability Theory and Its Application*, John Wiley and Sons, Inc., New York, p. 364.

In this study the stationary structure of the check-out process was investigated. Intuitively, one feels that the check-out process will approach a steady state, because there are restoring forces within the system which attempt to keep down the length of queue. In many cases, a probabilistic picture of the steady state will give sufficient insight for understanding the system's overall behavior.

The check-out system can be in a number of possible states which are specified by the number of units in the system, waiting for service, in service, etc. The steady state solution gives us the probabilities that the system is in each of the possible states. The steady state solution for the queuing model specified in the previous section is as follows:[6]

Let

$P_n$: The probability that there are $n$ customers in the check-out system.

$\rho$: The ratio of the average arrival rate to the average service rate per channel, i.e., $\lambda/\mu$.

$m$: The number of check-out stands in operation.

$$(5)\qquad \begin{aligned} P_n &= P_0 \frac{\rho^n}{n!}, && 0 < n \leq m \\ P_n &= P_0 \frac{\rho^n}{m!m^{n-m}}, && n \geq m. \end{aligned}$$

Note that the series

$$\sum_{n=m}^{\infty} (P_n/P_0)$$

converges only if $(\rho/m) < 1$.[7] Given the state probabilities (5) and noting the restriction

$$\sum_{n=0}^{\infty} P_n = 1$$

[6] For the derivation of this stationary probability distribution, see W. Feller, *ibid.*, pp. 377–79.

[7] In non-mathematical terms, this condition states that the average number of customers that can be checked out per unit time must exceed the average number of customers to be checked out. If the condition does not hold, the system must eventually break down. The ratio $\rho/m$ is often called the relative traffic intensity. The term "relative" implies that the traffic is measured in relation to the capacity of the system.

Mathematically, the necessity for this condition can be seen as follows: Divide both sides of the second equation of (5) by $P_0$ and sum them over the index $n$ from $m$ to $\infty$.

$$\sum_{n=m}^{\infty} \frac{P_n}{P_0} = \frac{m^m}{m!} \sum_{n=m}^{\infty} \left(\frac{\rho}{m}\right)^n$$

The geometric series $\sum (\rho/m)^n$ will converge to a limit only if the individual term of the series is less than 1.

the probability that there is no customers in the system can be obtained as follows:

$$(6)\qquad \begin{aligned} 1 &= P_0\left[\sum_{n=0}^{m-1}\frac{\rho^n}{n!}+\frac{m^m}{m!}\sum_{n=m}^{\infty}\left(\frac{\rho}{m}\right)^n\right], \\ P_0^{-1} &= \sum_{n=0}^{m-1}\frac{\rho^n}{n!}+\frac{\rho^m}{m!}\,\frac{m}{m-\rho}\,. \end{aligned}$$

After the state probability distribution has been derived, one can proceed to calculate the expected values of a number of stochastic variables and some derived probabilities which are of interest in a queuing problem. Quantities of special interest in the current study are the expected number of customers waiting in line and the probability that the number of people waiting in line exceeds a certain prespecified number.

Let $L_q$ be the mean queue length. Since a queue exists when the number of customers exceeds the number of check-out stands in operation at any given time, i.e., $n>m$, the difference $n-m$ is defined to be the length of queue. Its expected value is

$$(7)\qquad \begin{aligned} L_q &= \sum_{n=m}^{\infty}(n-m)P_n \\ &= \frac{P_0\rho^{m+1}}{(m-1)!(m-\rho)^2}\,. \end{aligned}$$

Let $\Pr(q>q^*)$ denote the probability that the length of queue is greater than a fixed number $q^*$, where $q=n-m$. This probability can be derived by substituting $q+m$ for $n$ in the right hand side of the second equation of (5) and summing it over all those values of $q$ greater than $q^*$.

$$(8)\qquad \begin{aligned} \Pr\,(q>q^*) &= \sum_{q>q^*}\frac{P_0\rho^{m+q}}{m!m^q} \\ &= \frac{P_0}{m!}\,\frac{q^{m+q+1}}{m^{q^*}(m-\rho)}\,. \end{aligned}$$

### *Minimizing Expected Costs of Check-out Operation*

In order for management to decide what grade of check-out service should be provided to its customers, knowledge about the probability structure of a queuing process associated with the check-out operation alone is not sufficient. It is necessary to introduce cost concepts into the problem. By superimposing a cost structure on the queuing process, expected variable costs per unit time of the check-out operation under various conditions can be calculated.

The criterion of optimality adopted here is the minimization of expected costs incurred to super market management in providing check-out service per unit time. Notion of expected values is introduced so that probability calculus can be used to take account of random elements in the queuing process.

In the short run, the management has little control over the flow of customers to its store, and it cannot modify the physical set-up of the store by installing more check-out counters. However, the average service rate of the check-out operation can be regulated by varying the number of check-out stands to be kept open as well as the number of package boys to assist cashiers. These are the two controllable variables which the management wishes to manipulate in such a way that the criterion of optimality can be met.

For each combination of the controllable variables selected, certain costs can be expected to arise. These costs can be classified into two types. They are: (1) wages of checkers and package boys, and (2) cost incurred by a loss of the store's good will due to frequent formation of long queues because of inadequate checkout service. The first kind of cost can be readily determined. On the contrary, the second kind of cost is rather elusive to determine. The thing to be quantified is the adverse effect of keeping a customer waiting too long and too frequently for check-out service. He may become impatient while waiting and decide not to return in the future. It can be hypothesized that this cost is a function of the expected length of queue and probably increases at an increasing rate as the expected length of queue increases. The optimizing procedure prescribed here is to seek a balance between these two costs so that the sum of these costs will be a minimum.

The above discussion can be more compactly stated with use of symbols. Let

$P_n$: Probability that there are $n$ customers in the system.
$C_1(m, k)$: Cost per unit time of employing $m$ checkers and $k$ package boys where $m \geq k$.[8]
$C_2(L_q)$: Penalty cost per unit time when the mean queue length is $L_q$.
$EC(m, k \mid \mu, \lambda)$: Expected cost of providing the check-out service for given value of $\lambda$ and $\mu$.

The expected cost is

$$EC(m, k \mid \mu, \lambda) = \sum_{n=0}^{\infty} [C_1(m, k) + C_2(L_q)]P_n. \tag{9}$$

[8] The functional notation is to emphasize the dependence of the cost function on the number of checkers and number of package boys. Similar remarks apply to the penalty cost function.

The criterion of optimality dictates that appropriate values of $m$ and $k$ be chosen to minimize the function (9). The equation (9) can be somewhat simplified if one notes that $C_1(m, k)$ is independent of the stationary distribution $P_n$. Thus, (9) can be reduced to

$$EC(m, k \mid \mu, \lambda) = C_1(m, k) + \sum_{n=0}^{\infty} C_2(L_q)P_n. \tag{10}$$

For the case at hand, the following assumptions were made in the course of deriving optimizing procedures:

(1) It is quite common for a super market to set up an express check-out stand to accommodate those customers with a relatively small number of purchases. Since the volume of daily sales made at this counter is generally small in comparison to the total daily sales of the store, the model used here takes no account of this practice.

(2) The second assumption is that there should not be more package boys than checkers at any time. This assumption seems to be in accord with the general practice. Because of this assumption, $EC(m, k \mid \mu, \lambda)$ is evaluated at most at $m(m+3)/2$ points. Since in most super markets the number of check-out stands rarely exceeds ten, evaluation of the expected cost function is not unmanageable even without the service of a high-speed computer.

(3) The presence of a long queue has no effect on the speed of service. This assumption could be relaxed if one allows different service rates for different types of traffic intensity.

### *Some Specific Formulations of Expected Cost Function*[9]

Three different expected cost functions based on (9) were formulated. Their differences lie in the nature of the penalty cost function assumed. In the first formulation, a penalty cost function was introduced in terms of the dollar value of the "good will" lost as a result of keeping one customer waiting in line per unit time. In the remaining two, the length of queue was incorporated indirectly into the expected cost function as a constraint of minimization.

#### *Formulation I*

(11) Minimize $(m - k)W_1 + kW_2 + \delta(L_q)$ with respect to $m$ and $k$,

where

$m$: The number of counters in operation or the number of checkers
$k$: The number of package boys, $(0 \leq k \leq m)$

[9] The author has benefited from suggestions by R. L. Gustafson of Michigan State University in preparing the materials contained in this section. Needless to say, any error is the author's sole responsibility.

$W_1$: Cost per unit time of operating a counter without a package boy
$W_2$: Cost per unit time of operating a counter by a checker and a package boy
$L_q$: Expected length of queue
$\delta$: Penalty cost function which is assumed known to management.

If $\delta$ is assumed to be a linear function, (11) can be written as follows:

$$(m - k)W_1 + kW_2 + d\,\frac{P_0\rho^{m+1}}{(m-1)!(m-\rho)^2} \tag{12}$$

where $d$ is a coefficient of the linear function which represents the dollar value of the good will lost when a customer has to wait for one unit time, and the explicit expression for $L_q$ (equation 7) has been inserted.[10]

*Formulation II*

(13) Minimize $(m-k)W_1+kW_2$ with respect to $m$ and $k$, subject to $L_q<L^*$

where $L^*$ is the maximum allowable queue length and is a parameter set by management.

*Formulation III*

(14) Minimize $(m - k)W_1 + kW_2$ with respect to $m$ and $k$, subject to $\Pr(q > q^*) < P^*$

where

$q$: The number of customers waiting in line
$q^*$: A fixed length of queue
$p^*$: Probability level specified by management

By inserting the explicit formulation for $\Pr(q>q^*)$ as in equation (8), the constraint can be stated as follows:

$$\frac{P_0\rho^{m+q^*+1}}{m!m^{q^*}\cdot(m-\rho)} < P^*$$

The last two formulations of the problem appear to be more adaptable to management's traditional and intuitive way of thinking, because the management is usually more willing to specify parameters such as $L^*$, $q^*$, and $P^*$ than to specify a penalty cost function $\delta(L_q)$.

## *Some Empirical Results*

The optimization procedures described in the previous sections were applied to the check-out operation at one of the nationally known food

[10] Note that in equation (12), the relative traffic intensity $\rho$ is a function of $m$ and $k$, since $\rho=(\lambda/\mu)$ and $\mu$ is a function of $m$ and $k$ as defined in equation (1).

chain stores in the Detroit area. This store does a weekly business of better than $50,000. It is considered to be a typical super market by the management as far as the purchasing patterns of its customers are concerned. Approximately one-fourth of the total weekly sales occur during the first three days of the week; Friday and Saturday together usually account for nearly one-half of the weekly sales; the remaining one-fourth of the business is credited to Thursday. This store has seven regular check-out stands and one express check-out stand. The latter accounts for less than five per cent of the total weekly sales. Like many supermarkets, the operation of check-out service is based on the composite judgement of the manager as to what is a uniformly good service and what is an economically efficient check-out service.

First, the week was subdivided into five periods so that within each period the average customer arrival rate may be, roughly speaking, neither

TABLE 1. CUSTOMER ARRIVAL GOODNESS-OF-FIT

| Period | Average Arrival rate (customers/min.) | Chi-square Statistic | Degree of Freedom | Significance Level of Chi-square Test (percent) |
|---|---|---|---|---|
| Mon., Tue., Wed. | 0.91 | 3.897 | 4 | 99 |
| Thurs. | 1.50 | 7.155 | 12 | 90 |
| Fri. before 6 p.m. | 1.77 | 8.107 | 8 | 25 |
| Fri. after 6 p.m. | 2.56 | 13.193 | 6 | 5 |
| Sat. | 2.44 | 3.828 | 6 | 75 |

rising nor falling. This was to ensure the validity of a steady state solution. For each period, the average arrival rate and average service rate were estimated by means of the maximum likelihood method.[11] Based on these estimates, the assumptions of Poisson input and exponential service time were tested by the chi-square test of goodness-of-fit. Finally the optimum combinations of checkers and package boys were calculated. These results were conveniently summarized in tabular forms.

The assumption of Poisson input appeared to be satisfactory. In the last column of Table 1, the "smallest" significance level at which the null hypothesis (i.e., a distribution is Poisson) is rejected is tabulated. If $\alpha$ is the tabulated value, the null hypothesis is rejected for any significance level $\alpha_1 \geq \alpha$ and is not rejected for $\alpha_1 < \alpha$. Hence, the larger the tabulated significance level is the more likely the assumption of Poisson input holds.

The assumption that service time is exponentially distributed was also tested by the chi-square test. Calculated statistics for the two kinds of service time, (a checker alone at a check-out stand, and both a checker and

[11] The estimation procedure and some properties of the estimates are discussed in the appendix.

a package boy at the stand) were relatively large. This indicated that the data fit poorly to the negative exponential distribution. This might have been expected because the assumption of a negative exponential distribution implies that the frequency of occurrence of zero service time will be the largest, i.e., $\mu e^{-\mu t}$ reaches its maximum, at $t=0$. Ordinarily one would expect the highest frequency of check-out service times to be clustered around a certain average value which is greater than zero. Further examination of the data indicated that they might have been fitted better to another member of the gamma function family.[12] Although a queuing model with such a service time distribution could be formulated, the mathematics involved for obtaining formulae such as equations (5) and (6) would become exceedingly difficult. Therefore, no further experimentation was carried out in this direction.

Table 2 is the table used to determine optimum check-out combinations for a typical Saturday in the super market under study. Similar tables were constructed for each of the periods.

The selection of parameters used in Table 2 needs some explanation. When the a priori impression of those who are informed about check-out operations was sought in regard to the maximum length of queue that could be tolerated, it was indicated that if there were not more than two persons waiting in each lane probably little adverse effect would result.[13] They also indicated that the situation would be considered under control if the probability of having more than two customers waiting in each check-out lane is less than 5 per cent. Since no suggestion could be obtained from the management as to the size of the coefficient $d$, it was assumed that keeping one customer waiting in line for one minute would cost 2¢. Probably this is not too far from what might be the average customer's subjective evaluation of his time.

Even if the management is unable to specify accurately parameters necessary for optimization, the content of Table 2 would still provide useful information because it has narrowed down a range of selection for optimum combinations of checkers and package boys. As mentioned previously,

[12] The function fitted was

$$f(t) = \frac{\beta^r}{(r-1)!} t^{r-1} e^{-\beta t}.$$

The calculated chi-square statistic against this distribution was 8.793. For 9 degrees of freedom, the null hypothesis need not be rejected at the 50 per cent significance level.

[13] They also felt that customers seem to consider a waiting line of, say, two persons when all the check-out lanes are open qualitatively different from the same length of waiting line when some check-out counters are idle. Apparently the customer is less irritated by a long wait if he sees that the management is making a reasonable effort to handle the traffic by opening more counters or placing more package boys. This is one of the factors that has to be considered in assigning a proper weight to the penalty cost function. In the present analysis, however, this information was not used because it was not available in quantitative forms.

TABLE 2. OPTIMUM CHECK-OUT FACILITIES FOR SATURDAY
(Estimated Average Arrival Rate = 2.44 customers/minute)

| Relative traffic intensity $\rho$ | No. of checkers $m$ | No. of package boys $k$ | Wages[a] $(m-k)W_1+kW_2$ | Expected length of queue[b] $L_q$ | Prob. of queue length exceeding $2m$ customers[c] $\Pr(q>2m)$ | Wages and penalty costs[d] | Optimum facilities according to various cost formulations[e] |
|---|---|---|---|---|---|---|---|
| | | | ¢/min. | | % | ¢/min. | |
| 6.03 | 7 | 0 | 19.67 | 3.870 | 6.91 | 32.44 | |
| 5.17 | 6 | 1 | 18.42 | 4.060 | 10.89 | 31.82 | |
| 4.31 | 5 | 2 | 17.17 | 4.263 | 13.30 | 31.24 | |
| 3.46 | 4 | 3 | 15.92 | 4.416 | 18.67 | 30.49 | II |
| 5.28 | 7 | 1 | 21.23 | 1.219 | — | 25.35 | |
| 4.52 | 6 | 2 | 19.98 | 1.305 | 1.16 | 24.29 | |
| 3.77 | 5 | 3 | 18.73 | 1.439 | 1.97 | 23.49 | |
| 3.01 | 4 | 4 | 17.48 | 1.562 | 4.16 | 22.63 | III |
| 4.69 | 7 | 2 | 22.79 | 0.517 | — | 24.50 | |
| 4.02 | 6 | 3 | 21.54 | 0.587 | — | 23.48 | |
| 3.31 | 5 | 4 | 20.29 | 0.625 | — | 22.35 | I |
| 4.22 | 7 | 3 | 24.35 | 0.254 | — | 25.19 | |
| 3.62 | 6 | 4 | 23.10 | 0.304 | — | 24.10 | |
| 3.01 | 5 | 5 | 21.85 | 0.360 | — | 23.03 | |
| 3.84 | 7 | 4 | 25.91 | 0.138 | — | | |
| 3.29 | 6 | 5 | 24.66 | 0.171 | — | | |
| 3.52 | 7 | 5 | 27.47 | 0.078 | — | | |
| 3.01 | 6 | 6 | 26.22 | 0.101 | — | | |
| 3.25 | 7 | 6 | 29.03 | 0.047 | — | | |
| 3.01 | 7 | 7 | 30.59 | 0.028 | — | | |

[a] The values of $W_1$ and $W_2$ used in this study were 2.81¢ and 4.37¢ respectively.

[b] The maximum allowable queue length $L^*$ was assumed to be $2m$, i.e., two customers per check-out lane.

[c] A dash indicates that the probability is less than 1 per cent. The assumed value of $P^*$ was 5 per cent.

[d] Figures in this column are based on equation (12). No entry in this column indicates that the cost for adopting that particular check-out combination is too high for further consideration.

[e] The Roman numerals I, II and III refer to the specific formulations of cost functions associated with equations (12), (13) and (14), respectively. For instance, the Roman numeral II should be interpreted as follows: for $m=4$ and $k=3$, the cost function in Formulation II attains its minimum point.

combinations considered in the table are limited to those which satisfy the condition for the convergence of the stationary probability distribution, $(\rho<m)$. Hence, all the combinations in the table may be considered to have passed the initial screening. In general, a combination of checkers and package boys which generates higher operating cost tends to be associated with a better grade of service as indicated by a shorter expected length of queue and smaller $\Pr(q>2m)$. However, there are some exceptions to this ten-

dency. Some combinations in Table 2 illustrate this point. For instance, the combination ($m=5$, $k=3$) is to be preferred to the combination ($m=7$, $k=0$), because the former brings about better service with smaller cost as compared to the latter.

Optimum check-out facilities as presented in Table 2 were determined by first estimating the average arrival rate and the average service rate and then using these estimated values as though they were "true" values in the formulation of costs functions, (12), (13) and (14). In practice, these estimates are subject to sampling errors. Hence, it is natural to inquire about the effects of incorrect specifications of the average arrival rate and the average service rate on the choice of optimum check-out facilities.

The most important item to be considered is the variation in $\rho$ as estimates of $\lambda$ and $\mu$ fluctuate. This is done by obtaining high-side and low-side estimates of $\rho$ from confidence limits of $\lambda$ and $\mu$.[14]

TABLE 3. EFFECT OF VARIATION IN ESTIMATES OF $\lambda$ AND $\mu$ UPON OPTIMUM CHECK-OUT COMBINATIONS

| Relative Traffic Intensity | Formulation I | | Formulation II | | Formulation III | |
|---|---|---|---|---|---|---|
| | $m$ | $k$ | $m$ | $k$ | $m$ | $k$ |
| High-side estimate of $\rho$ | 5 | 5 | 4 | 4 | 5 | 4 |
| $\rho$ | 5 | 4 | 4 | 3 | 4 | 4 |
| Low-side estimate of $\rho$ | 4 | 4 | 3 | 3 | 4 | 3 |

Let $\lambda^*$ and $\lambda_*$ be the upper and lower confidence limits respectively of $\lambda$ for a given size of confidence coefficient; similarly $\mu^*$ and $\mu_*$ are the upper and lower limits of $\mu$.[15] $\rho$ would then vary between its high-side estimate $\lambda^*/\mu_*$ and low-side estimate $\lambda_*/\mu^*$. The effect of variations in $\lambda$ and $\mu$ on optimization can be studied by obtaining optimum combinations corresponding to these estimates.

In Table 3, the optimum check-out combinations for a typical Saturday based on the high-side and low-side estimates of the relative traffic intensity $\rho$ are compared with those presented in Table 2. As can be seen from this table, the determination of optimum check-out combinations by the methods proposed here was not very sensitive to variation in estimates of $\lambda$ and $\mu$ due to sampling errors.

## *Appendix*

In the theoretical study of the probability structure associated with a queuing problem, values of average service rate and average arrival rate or their reciprocals, average service time and average length of time be-

[14] The derivation of confidence limits of $\lambda$ and $\mu$ is presented in the appendix.

[15] Since $\mu$ is calculated by (1), $\mu^*$ is obtained by inserting upper confidence limits of $\mu_1$ and $\mu_2$ in (1). Similarly, $\mu_*$ is obtained by inserting lower confidence limits of $\mu_1$ and $\mu_2$ in (1).

tween successive customer arrivals, are considered to be known a priori. In any practical problem, however, these quantities must be estimated from a finite number of samples. Estimates of these quantities are subject to sampling fluctuations. In the following pages, the estimation problem is considered first. This is followed by some discussion on statistical properties of the estimators. While remarks and illustrations will deal with the average service time, the general conclusions are applicable also to the average length of time between successive customer arrivals, because service times and intervals between consecutive customer arrivals are both assumed to be exponentially distributed.

Let $t_1, t_2, \cdots, t_n$ be $n$ independent observations on service time. Each of them is assumed to be distributed by the negative exponential distribution $\mu e^{-\mu t}$. Let $\hat{\mu}$ denote an estimate of $\mu$. It is defined as follows:

$$\text{(A1)} \qquad \hat{\mu} = \frac{n}{\sum_{i=1}^{n} t_i} \cdot$$

$\hat{\mu}$ is the value of the average service rate that maximizes the logarithm of the likelihood function

$$\text{(A2)} \qquad L = n \ln \mu - \mu \sum_{i} t_i.$$

A point estimate of the average service rate is not very meaningful without some measure of the possible error in the estimate. The estimate $\hat{\mu}$ of the parameter $\mu$ should be accompanied by some interval about $\hat{\mu}$, possibly of the form $(\hat{\mu}-a)$ to $(\hat{\mu}+b)$, together with some measure of assurance that the true parameter $\mu$ does lie within the interval. In order to derive such an interval, it is convenient to consider the quantity $\theta$ which is the reciprocal of $\mu$, and derive the sampling distribution function of $\hat{\theta}$,

$$\hat{\theta} = \frac{\sum_{i=1}^{n} t_i}{n},$$

which is the maximum likelihood estimate of $\theta$.

The density function and cumulative distribution function of $\hat{\theta}$ are as follows:

$$\text{(A3)} \qquad f(\hat{\theta}) = \frac{(n/\theta)^n}{(n-1)!} \hat{\theta}^{n-1} e^{-(n/\theta)\hat{\theta}},$$

$$\text{(A4)} \qquad \int_0^y f(\hat{\theta}) d\hat{\theta} = 1 - e^{-(n/\theta)y} \sum_{i=1}^{n} \frac{[(n/\theta)y]^{i-1}}{(i-1)!} \cdot$$

The cumulative distribution function (A4) is an incomplete gamma function and can also be considered as a right-hand tail of the Poisson distribution with the parameter $(n/\theta)y$.

From (A4) a probability statement of the form

$$\text{(A5)} \qquad \Pr\,(t_1 < \hat{\theta} < t_2) = \int_{t_1}^{t_2} f(\hat{\theta})d\hat{\theta} = \gamma$$

can be made. $\gamma$ is called the fiducial probability or confidence coefficient. Unfortunately the statement (A5) involves the unknown parameter $\theta$. In order to get around this difficulty, it is necessary to obtain a distribution of $\hat{\theta}$ which is entirely free of the unknown parameter. This can be done by transforming $\hat{\theta}$ to $z$ according to the following formula:[16]

$$\text{(A6)} \qquad z = \frac{\hat{\theta} - \theta}{\dfrac{\theta}{\sqrt{n}}}\,.$$

The density function of $z$, $g(z)$ is

$$\text{(A7)} \qquad g(z) = \frac{(\sqrt{n})^n(z + \sqrt{n})^{n-1}}{(n-1)!}\, e^{-\sqrt{n}(z+\sqrt{n})}.$$

And its cumulative distribution function is

$$\begin{aligned} \int_0^b g(z)dz &= \Pr\,(z < b) \\ \text{(A8)} \qquad &= \Pr\left(\hat{\theta} < \theta\,\frac{b + \sqrt{n}}{\sqrt{n}}\right) \\ &= 1 - e^{-\sqrt{n}(\sqrt{n}+b)} \sum_{i=1}^{n} \frac{[\sqrt{n}(b + \sqrt{n})]^{i-1}}{(i-1)!}\,. \end{aligned}$$

By means of the distribution (A8), the values of constants $b$ and $a$ satisfying the following probability statements

$$\Pr\,(z < b) = \gamma_1$$
$$\Pr\,(z < a) = \gamma_2$$

can be found. $\gamma_1$ and $\gamma_2$ are any given probability levels. In particular, this can be done for those values of $\gamma_1$ and $\gamma_2$ which meet the following conditions

$$\gamma_1 - \gamma_2 = \gamma$$

[16] Note that $E(\hat{\theta}) = \theta$ and $Var(\hat{\theta}) = \theta^2/n$.

and

$$1 - \gamma_1 = \gamma_2$$

where $\gamma$ is another arbitrarily specified probability level. Thus, one can make probability statements such as (A5).

In practice the constants $a$ and $b$ can be readily determined by use of a chart showing the cumulative Poisson distribution for a number of different values of the parameter. This chart was prepared by the Bell Telephone engineers.[17] The function

$$1 - e^{-\beta} \sum_{i=1}^{n} \frac{\beta^{i-1}}{(i-1)!}$$

is plotted in the chart for values of $\beta$ ranging from 0 to 200 and $i$ from 0 to 270. After the interval $(a, b)$ which satisfies the following probability statement

$$\Pr (a < z < b) = \gamma$$

has been found, the probability statement can be readily transformed to

$$\text{(A9)} \qquad \Pr\left(\frac{a + \sqrt{n}}{\sqrt{n}\,\hat{\theta}} < \mu < \frac{b + \sqrt{n}}{\sqrt{n}\,\hat{\theta}}\right) = \gamma$$

since

$$z = \frac{\hat{\theta} - \theta}{\dfrac{\theta}{\sqrt{n}}} \quad \text{and} \quad \theta = \frac{1}{\mu} \cdot$$

The interval in (A9) will cover the true value of $\mu$ with the $\gamma$ per cent probability.

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[17] Molina, op. cit.

# EMPIRICAL PRODUCTION FUNCTION FREE OF MANAGEMENT BIAS[1]

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## *Introduction*

IT HAS been felt for a long time that the estimates of the parameters of production functions are subject to bias as a result of excluding the variable which represents management. The reason for omitting management from cross-section analysis is obviously the lack of units for its direct measurement. An attempt to substitute some index of management does not solve the conceptual difficulty. It can be regarded as an ad hoc procedure as long as no criterion for evaluating its performance is available.

Instead of beginning by conceptualizing what we mean by management we shall assume that whatever management is, it does not change considerably over time; and for short periods, say a few years, it can be assumed to remain constant. For the purpose of the following analysis it is sufficient that management remains fixed for a two-year period since at least two observations on each firm are required.[2] In this framework we shall show how covariance analysis is used to obtain unbiased estimates of the coefficients of the linear form of the production function.[3] We shall evaluate the bias which would have been obtained in a regular regression estimate, that is, one subject to a particular specification error. We shall then show how management can be estimated up to a multiplier.

## *The Model*

The procedure deals with the linear form of a production function. This includes the Cobb Douglas function where the variables are written in logarithms. Let it be:

$$(1) \qquad Y_{it} = B_0 + B_1X_{1it} + \cdots + B_kX_{kit} + CM_i + e_{it}$$

where $Y$ is output, $X_1, \cdots, X_k$ are inputs, $M$ is management, $e$ is the disturbance, $B_j$ and $C$ are the true coefficients to be estimated;

$$i = 1, \cdots, I \qquad t = 1, \cdots, T$$

The usual procedure in cross section studies is to fit a regression to data collected for firms at a point of time, ignoring the term $CM_i$. This term

[1] I have benefited from comments by Y Grunfeld, S. Hoos and J. Putter. I am particularly indebted to N. Liviatan whose valuable suggestions are well reflected in the paper.

[2] It seems desirable to qualify the statement: (a) When there is a reason to believe that management changes from one year to the next, then the approach suggested above cannot be applied to annual data. (b) However, it can be applied for shorter periods, say months.

[3] The same technique was previously used by Hoch: Hoch, Irving, "Estimation of production function parameters and testing for efficiency," *Econometrica* 23:326 (1955).

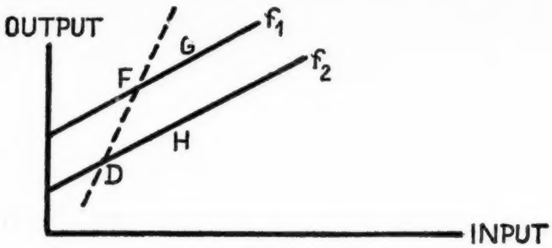


FIG. 1

varies from firm to firm and thus leads to a different production function for each firm. In the linear form of the functions, the difference is in the $y$-intercept of the lines. The slopes of the linear form are specified to be the same for different firms. In Figure 1 we have two functions, $f_1$, $f_2$, which represent output as a function of a single input, both having the same slope but different intercepts. If the level of management were the same, the two lines would coincide. Otherwise, they are not the same and the cross section fit is made over points such as $D$, $F$.[4] In the case of a Cobb Douglas function the lines represent the logarithmic form where the actual form can be drawn as in Figure 2. The form of the "interfirm" function $DF$ is not the same as that of the "intrafirm" functions $f_i$. Furthermore, it is not uniquely determined by the intrafirm function unless the particular competitive form of the market is specified and conditions of equilibrium are imposed.[5] That means, in turn, that the knowledge of $DF$ does not secure the knowledge of $f_i$.

There are two pertinent questions in cross section analysis:

(1) How to estimate the slope of $f_i$, the intrafirm function?

(2) Which function is more useful, the "intrafirm" or the "interfirm"?

In this paper we shall deal only with the first question and at this stage will only comment on the second one. The key to the estimation of the slope of the intrafirm function is to have at least two points on each $f_i$. In this case it is possible to get the slope of each of the lines $f_i$, average them and get the final estimate. That requires a combination of time series and cross-section data. The two observations can be collected in two successive years on the same sample of firms.

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[4] There is some similarity to problems involved in fitting a production function to time series data. Under conditions of technological change, observations for the various years belong to different functions. The solution is, however, different. This problem is dealt with by: Solow, Robert M., "Technical change and the aggregate production function," *Rev. Econ. and Stat.*, 39:312–21 (1957).

[5] Bronfenbrenner, M., "Production Function: Cobb-Douglas, Interfirm, Intrafirm," *Econometrica*, 12:37–38, (1944).

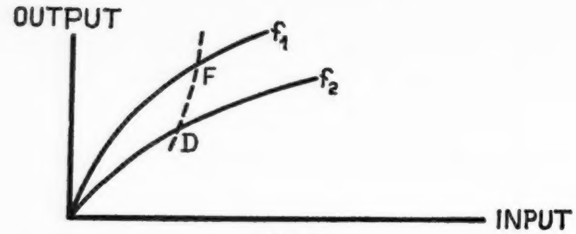


FIG. 2

The statistical treatment is in the framework of the analysis of covariance.[6] The sum of squares

$$\mathcal{S} = \sum_{it} (Y_{it} - B_0 - B_1X_{1it} - \cdots - B_kX_{kit} - A_i)^2 \tag{2}$$

is minimized with respect to the various parameters.

Since there are no observations on the management variable $M$, it is impossible to estimate $C$ directly. The minimization is therefore made with respect to the product:

$$A_i = CM_i \tag{3}$$

This does not cause any difficulty. Not only are there no observations on $M_i$, but also the units by which management is measured are arbitrary and it makes no difference if all the $M_i$ are multiplied by the same constant.

With no loss in generality set $\sum_i A_i = 0$ and obtain the estimates:

$$b_0 = Y_{..} - b_1X_{1..} - \cdots - b_kX_{k..} \tag{4}$$

$$a_i = Y_{i.} - b_1X_{1i.} - \cdots - b_kX_{ki.} - b_0 \tag{5}$$

$$(b) = (S_{yx})(S_{xx})^{-1} \tag{6}$$

where

$$X_{1..} = \frac{1}{IT}\sum_i \sum_t X_{1it}, \qquad X_{1i.} = \frac{1}{T} \sum_t X_{1it}, \text{ etc.}$$

$(b)$ is a row vector of the $k$ regression coefficients, $(S_{yx})$ is a row vector of $k$ sample moments with typical element:

$$s_{yx_l} = \frac{1}{IT}\left[\sum_i \sum_t Y_{it}X_{it} - T\sum_i Y_{i.}X_{i.}\right] \tag{7a}$$
$$l = 1, \cdots, k$$

$(S_{xx})^{-1}$ is the inverse of the matrix of the sample moments of the independent variables with typical element:

[6] A systematic discussion on covariance analysis can be found in Scheffé, H., *The Analysis of Variance* (Wiley, 1959), ch. 6.

$$s_{x_l x_r} = \frac{1}{IT}\left[\sum_i \sum_t X_{lit}X_{rit} - T\sum_i X_{li\cdot}X_{ri\cdot}\right] \tag{7b}$$
$$l, r = 1, \cdots, k$$

It is seen that the moments are computed from the average for each firm and represent the variations "within" firms.

If the assumptions of classical regression hold and if the function is completely specified, then the estimates obtained are unbiased and best. This is not the only accomplishment. We also get estimates, $a_i$ of $A_i$, that is, estimates of the management variable. Such estimates may provide the dependent variable for studies aimed at exploring factors which determine the quality or performance of management.[7]

What is still missing is the estimate of $C$. This can only be obtained by introducing outside information. If the production function is complete and the factors are divisible we can impose the condition of constant returns to scale, which leads to:[8]

$$C = 1 - \sum_j^k B_j \tag{9}$$

and the unbiased estimate of $C$ is

$$c = 1 - \sum_j^k b_j \tag{10}$$

Having obtained $c$, it is now possible to derive an estimate of the management variable with the original units. That is:

$$m_i = \frac{a_i}{c} \tag{11}$$

The advantage of (11) over (5) is in yielding a unique estimate of the management variable. Nevertheless it should be clear that for some purposes it is immaterial which of the two estimates is used.

If some other input, besides management, is fixed for all firms over the

[7] Such an approach has been attempted by Yaron in: Yaron, Dan, *Resource allocation for dairy and field crops in the Negev area of Israel*, unpub. Ph .D thesis, Iowa State Univ. Libr., Ames, Iowa, 1960.

[8] There is no unanimous agreement on the role of the divisibility approach to the explanation of economies of scale. The device suggested in the text is only pertinent for the supporters of the approach. For the others it can taken be as an ad hoc procedure Objection to the divisibility approach can be found in: Chamberlin, E. H. "Proportionality, Divisibility and Economies of Scale," *Quar. J Econ.* Feb. 1948, pp. 229–62; or *The Theory of Monopolistic Competition*, Cambridge: Harvard Univ. Press, 6th or 7th ed., Appendix B; also Leibenstein, H., "The proportionality controversy and the theory of production," *Quar. J. Econ.*, Nov. 1955, pp. 619–26.

two year period, its regression coefficient will be zero. The other coefficients remain unbiased but (10) is not directly applicable. In addition, $a_i$ will now be an estimate of management and the "fixed" input combined.

In applying this analysis to agriculture, there is a danger that in what we refer to as management we also include a farm effect; that is, the effect of factors which do not depend on the management but rather on the particular environmental conditions of the farm, such as climate, type of soil, topography, etc. This would not affect the estimates $b_j$ or their properties, but it will change the meaning of $a_i$. It will now be an estimate of the management and farm effect combined. If there is a possibility of grouping the farms into homogeneous groups, say villages, and if management is randomly distributed over these villages, an introduction of a parameter to represent the village effect may eliminate some of the farm effect.

### *The Management Bias in the Interfirm Regression*

An important feature of the interfirm regression is its dependence on the particular position of the individual firms on their own production function. Referring to Fig. 1, it is noted that a regression connecting the points *DF* will be different from that connecting *DG* or *FH*. Even if we impose the condition that the firms are in equilibrium, the data on which the equilibrium position depends may vary from one year to the next and thus the interfirm regressions will vary over years. Such changes do not affect the intrafirm regression since, if the firms are found on their particular production function, we always obtain estimates of the same slope regardless of the position.

It has been shown that the regression coefficients of an equation not completely specified are subject to a bias.[9] In the case of a cross-section regression for year $t$ we have:

$$E[\, \bar{b}_{jt} - B_j] = Cd_{jt} \tag{12}$$

where $\bar{b}_{jt}$ is the regression coefficient of the biased regression in year $t$ and $d_{jt}$ is the regression coefficient of the $j$th input in the auxiliary regression of $M$ on all the $k$ inputs included in the analysis. Averaging these coefficients $\bar{b}_{jt}$ over $t$ and subtracting $B_j$ will give the average bias. In order to estimate the bias it is possible to substitute for $B_j$ its unbiased estimate obtained from (6). That will yield the auxiliary regression up to a multiplier $C$. If we are willing to take $c$ of (10) as an estimate of $C$, we have the estimated auxiliary regression. It can be written as:

$$M_i = d_1 X_{1i} + \cdots + d_k X_{ki} \tag{13}$$

[9] Theil, H., "Specification Errors and the Estimation of Economic Relationships." *Rev. Internat. Stat. Inst.*, 25:41–51 (1957); Griliches, Zvi, "Specification Bias in Estimates of Production Functions," *J. Farm Econ.*, 39:8–20 (1957).

This is an empirical regression which describes the particular relationship between management and the other inputs as they exist in the sample. As such it may be very useful since it suggests a way to compose a management index for firms which belong to the same population from which the sample was drawn. Equation (13) does not explain what determines the performance of the management. It only describes how management is reflected in the level of input utilization.

It is also possible to estimate (13) directly, once the variable $a_i$ is available. This can be done by computing the regression of $a_i$ on all the included variables. This actually amounts to the use of the numerical values ob-

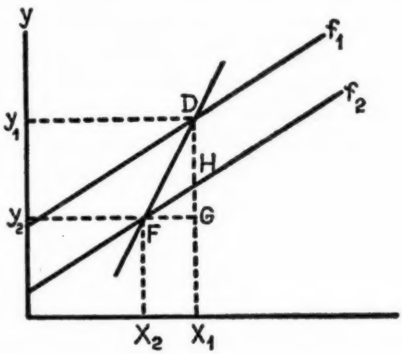

FIG. 3

tained from (5) for $a_i$ instead of substituting the sample statistics as was done here. The results should therefore be the same. It can be shown, however, that statistically either one of these methods is not as efficient as estimating $C$ directly if one could observe $M_i$; that is, if management could be treated just as another variable.

The relation between the interfirm function, the intrafirm function and the auxiliary equation can be demonstrated graphically for the simple case of $k=1$ (Fig. 3).

The interfirm function passes through points $FD$, with slope

$$\bar{b} = \frac{Y_1 - Y_2}{X_1 - X_2}\,.$$

The slope of the intrafirm function is

$$B = \frac{H - G}{X_1 - X_2} \text{ and the difference } \bar{b} - B = \frac{D - H}{X_1 - X_2} = C\frac{(M_1 - M_2)}{X_1 - X_2} = Cd$$

is equal to the slope of the equation expressing $CM_i$ as a linear function of $X$. It turns out that the assumption of constant slope of the interfirm

function over time is actually an assumption about the relationship between the management variable and the level of input utilization. The slope of the interfirm function can be thought to consist of two components, $B$ and $Cd$. The first is constant over time by assumption. Therefore, assuming that $Cd$ is constant will make $\bar{b}$ constant.

A similar figure can be drawn for a case where $\bar{b}$ is smaller than $B$ but still positive. In that case $Cd$ will be negative but smaller than $B$. If $Cd$ is negative and larger than $B$, then $\bar{b}$ becomes negative. That is, if the better managers employ less of the particular input than the worse managers, then the slope of the interfirm function will be smaller than that of the intrafirm and may also turn out to be negative.

*Empirical Results*

The method is demonstrated by giving results of an analysis of 66 family farms in Israel.[10] The data were collected for the years 1954–58. The variables included in the regression are:

$Y$ = value of product
$X_1$ = number of labor days
$X_2$ = variable expense
$X_3$ = value of livestock at the beginning of the year
$X_4$ = value of livestock and poultry barns measured in I£. The value was derived by first measuring the capacity of the barns disregarding age differences. The capacity values were then multiplied by the market price.
$X_5$ = amount of land on irrigated area basis (1 irrigated dunam = 4 dunams of dry land; 1 dunam = $\frac{1}{4}$ acre).

All flow variables are annual measures. All value variables are measured in I£ in 1954 prices. In order to give some notion as to the size and structure of farms included in the study, the first line of Table 1 gives the values for geometrical means of the various variables.

Before presenting the results we should consider an additional point which now becomes pertinent to the discussion. Underlying our model is the assumption that neither the production function nor management changes over time within the period under consideration. There is little that we can do about taking variations in management into account. However, with respect to the production function we can allow for a year effect which will shift the intercept of the function in its linear form. Such a procedure will catch changes in the level of productivity which occur in time. The empirical equation will be similar to (1) with additional term

[10] The results are taken from a forthcoming manuscript by the author: "Economic Analysis of Established Family Farms in Israel." The study has been made at the Falk Project for Economic Research in Israel.

$A_t$ which represents the effect of the year. We shall refer to the revised function as the one which represents the model, or better, the unrestricted function. We now present four sets of estimates of this function, obtained under various assumptions: (2a) is obtained under the assumption that there is neither a year nor a firm effect, that is, under the assumption of $A_i = A_t = 0$ for all $t$ and $i$. (2b) is obtained by allowing for a year effect, that is, under the assumption of $A_i = 0$ for all $i$. (2c) is obtained by allowing for a firm effect, that is, under the assumption of $A_t = 0$ for all $t$. (2d) is the unrestricted regression equation which allows for both a firm and a year effect. If we are willing to impose the a priori information that the function has not changed within the period without subjecting it to a statistical test, or if the result of such a test indicates no significant year effect, then the unbiased equation is (2c) and the management bias is evaluated by subtracting the estimates of (2c) from the values obtained in (2a). Otherwise, the unbiased equation is (2d) and the management bias is obtained by subtracting the value in (2d) from those in (2b). In our case the year effect was not significant at the 1 percent level, but passed the 2.5 percent mark. We view it as a borderline case and therefore report the two sets of results. The results appear in Table 1. In both sets of comparison the firm effect turns out to be highly significant. The implication is that the usual regression which is computed by not allowing for the firm effect is likely to be subject to a bias. The rejection of the hypothesis of no firm effect is a necessary condition for a management bias. The sufficient condition is a correlation between management and level of inputs. From (12) we know that the difference between the biased and unbiased coefficients yields estimates of the bias. Those values are estimates and as such are subject to sampling error. We shall not attempt here to test whether the bias of any particular coefficient is significantly different from zero. But we shall comment later on testing the hypothesis that the auxiliary regression is identically zero.

It is seen that both sets of estimates yield positive correlation between management and most of the inputs. In (3a), where no allowance is made for a year effect, negative relations are detected between livestock barns ($X_4$) and management. In (3b) the bias in $X_4$ disappears but negative relations are obtained between value of livestock at the beginning of the year ($X_3$) and management. The interpretation of a negative bias is that the better managers use less of the input with the negative coefficient, other things being equal. In the case of $X_3$, the regression coefficients were not significantly different from zero in both (2d) and (2b). Hence, it can be argued that the difference is also likely to be zero. In terms of Figure 3, the negative bias would be presented by drawing an interfirm line with a positive slope but smaller in magnitude than that of the intrafirm lines. The estimates of the relative bias appear in section 4 of Table 1. The values reach

TABLE 1

| Item | $X_1$ | $X_2$ | $X_3$ | $X_4$ | $X_5$ | Output |
|---|---|---|---|---|---|---|
| 1. Geometric means | 539 | 9900 | 1792 | 6621 | 255 | 18973 |
| 2. Estimated elasticities | | | | | | $\Sigma b$ |
| a. Data pooled | .130 | .692 | .0043** | .103 | .037 | .967 |
| b. Allowing for a year effect | .153 | .679 | .0042** | .101 | .032* | .969 |
| c. Allowing for a firm effect | .083* | .635 | .0021** | .156 | .002** | .878 |
| d. Allowing for both year & firm effects | .115 | .582 | .005** | .100* | −.007** | .795 |
| 3. Absolute bias | | | | | | |
| (a) Assumption of no year effect | .047 | .057 | .0022 | −.053 | .035 | |
| (b) Allowing for year effect | .038 | .097 | −.0008 | .001 | .039 | |
| 4. Relative bias | | | | | | |
| (a) Same as 3a | .57 | .09 | 1.00 | (−).34 | 17.5 | |
| (b) Same as 3b | .33 | .17 | (−).16 | .01 | 5.57 | |
| 5. $r_{ax}$ | | | | | | |
| (a) Same as 3a | .482 | .293 | .152 | .049 | .453 | |
| (b) Same as 3b | .602 | .617 | .135 | .402 | .492 | |
| 6. Equilibrium estimates | .135 | .574 | .010 | .096 | .013 | .828 |

Coefficients which are not marked are significant at the 1 percent level, those marked with * are significant at the 5 percent level and those marked with ** are not significant at the 5 percent level.

(3) a: obtained by subtracting values in 2c from those in 2a.
b: obtained by subtracting values in 2d from those in 2b.
(4) a: obtained by dividing values in 3a by values in 2c.
b: obtained by dividing values in 3b by values in 2d.
(5) Correlation coefficient of $a_i$ and input.
(6) See discussion in text for description.

considerable magnitude for some variables. It is particularly large for land where the unbiased coefficient is nearly zero.

Additional illustration can be performed with the results reported by Hoch. His analysis is "on 63 Minnesota farms over each of the 6 years from 1946 through 1951. Inputs were: $X_1$, labor; $X_2$, real estate; $X_3$, machinery; $X_4$, feed and fertilizer. Outputs and inputs were in service units, all variables being measured in dollars."[11] His regression coefficients of the Cobb-Douglas function and our computation of the bias are shown in Table 2.

There is a marked difference between the two regressions. In commenting on it Hoch said that a "possible explanation is that entrepreneurial capacity has been winnowed out by . . . (the unbiased regression in our terminology). It may also be that efficiency increases with scale."[12] The first sentence is a conjecture of the bias caused by the correlation between management and input. The second sentence can be interpreted as suggesting auxiliary regression with positive coefficients. Using (10) we can now get an estimate

[11] Hoch, Irving, *op. cit.*

[12] *Ibid.*

for $C$, the elasticity of management. The sums of the elasticities are .878 and .795 for the estimates without and with a year effect respectively. Consequently, the estimates of $C$ are .122 and .205 respectively. These values are relatively high and rank second in magnitude after the elasticity of current expense. The corresponding value for the Hoch study is .403 which is much higher than our results. It is interesting to note that the sum of the elasticities in the biased regressions are close to one, indicating

TABLE 2

| Item | $X_1$ | $X_2$ | $X_3$ | $X_4$ | $\Sigma_j b_j$ |
|---|---|---|---|---|---|
| 1. Biased regression | .2191 | .2173 | .2690 | .3006 | 1.0060 |
| 2. Unbiased regression | .0482 | .0550 | .2006 | .2927 | .5965 |
| 3. Absolute bias | .1709 | .1623 | .0684 | .0079 | |
| 4. Relative bias | .78 | .75 | .25 | .26 | |

Lines 1 and 2 are taken from Hoch. The estimates in the first line were obtained by covariance analysis, allowing for a year effect. The estimates in the second line were obtained by allowing for both a year effect and a farm effect. The values in the remaining two lines were obtained in the same way as in Table 1.

that the discrepancy in estimating the degree of the function is small, granted that the function is homogeneous of degree one. However, what is important here is the fact that the sum of the elasticities in the biased equation is larger than in the unbiased one. This should be anticipated in most cases unless some resources are used in such excessive amounts that they yield a negative relation with management that overcomes the positive relations with the other factors. That is to say that good management would have decreased the particular resource. When it is felt that this is not the situation, an inclusion of some management index worked out according to common sense should decrease the sum of the elasticities of the $k$ inputs. This is not a perfect indicator; it only gives a criterion for evaluating the direction of expected change but not its magnitude.

Utilizing the estimate of $C$ it is possible to derive the auxiliary regression with the original units:

$$\text{(a)} \qquad \hat{M} = H_a X_1^{.385} X_2^{.467} X_3^{.018} X_4^{-.434} X_5^{.287} \qquad R_m^2 = .263$$

$$\text{(b)} \qquad \hat{M} = H_b X_1^{.185} X_2^{.473} X_3^{-.004} X_4^{.005} X_5^{.190} \qquad R_m^2 = .416$$

$$\text{(c)} \qquad \hat{M} = H_c Z_1^{.421} Z_2^{.400} Z_3^{.168} Z_4^{.195}$$

where $\hat{M}$ is the value for $M$ derived from the auxiliary regression. The $Z$ values of regression (c) are the inputs in the Minnesota study. The $H$'s are the constants of the equations. The coefficient of determination of the auxiliary regression can be computed directly without having to first compute the $a$'s.[13]

[13] Utilizing the general expression for deriving the coefficient of determination, we can

The first two auxiliary regressions explain, respectively, 26 percent and 42 percent of the variations in management. In a regular regression such values lead to the rejection of the hypothesis of $R^2=0$, for a sample of the size used here. Such a rejection is the sufficient condition for having a bias in at least one coefficient of the regression which is subject to specification error. The necessary condition, as was pointed out earlier, is the rejection of the hypothesis of no firm effect.

The gross correlation coefficients between management and the various inputs appear in section 5 of Table 1 and are reported as $r_{ax}$. They were computed by following a similar procedure to that used in the computation of $R_m{}^2$. The values give some indication of the nature of the relationships that exist in the sample.

## *The Equilibrium Approach*

When management is treated symmetrically with the other inputs, the marginal productivity of management is $MP_M=CY/M$. An estimate of it can be obtained by substituting $c$ for $C$. At the point of the geometric mean of all the inputs the expression becomes $MP_M=c\overline{Y}$ where a bar stands in

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write in our notation:

$$R_m{}^2 = \frac{\sum_i (cd_j) s_{ax_j}{}^i}{s_a{}^2}$$

where $cd_j$ is the coefficient of $x_j$, uncorrected for $c$, in the auxiliary regression,

$$s_{ax_j}{}^i$$

is the cross product between $a$ and $x_j$, that is:

$$s_{ax_j}{}^i = \sum_i a_i X_{ji}$$

and $s_a{}^2$ is the sample sum of squares of $a$, that is:

$$s_a{}^2 = \sum_i a_i{}^2.$$

Utilizing (5) we get:

$$s_a{}^2 = [1,\ -b]\left[\begin{array}{c|c} S_{yy}{}^i & S_{yx_j}{}^i \\ \hline S_{yx_j}{}^i & S_{xx}{}^i \end{array}\right]\begin{bmatrix} 1 \\ -b \end{bmatrix}$$

where $b$ is the $1\times k$ vector of the unbiased regression coefficients and the $S^i$ matrix is symmetrical $(k+1)\times(k+1)$ with typical element

$$s_{uv}{}^i = \sum_i u_{i.}v_{i.} - Iu_{..}v_{..}$$

and $S_{ax}{}^i$ is obtained by

$$S_{ax}{}^i = [1,\ -b]\begin{bmatrix} S_{yx_j}{}^i \\ S_{xx}{}^i \end{bmatrix}$$

where $S_{ax}{}^i$ is a row vector of the

$$s_{ax_j}{}^i\text{'s}.$$

Thus, the computation of $R_m{}^2$ requires very few additional calculations.

this section for the geometric mean of the variable evaluated from the sample. It should be recalled that we previously assumed $\overline{M}=1$ and therefore $M$ does not appear in the expression. The interpretation of this expression is that the additional unit of management at the point of the geometric mean will increase output by $C\overline{Y}$. This is a high value which partially reflects the fact that a unit of $M$ was arbitrarily selected to be large.

Let us now assume perfect competition in which case the condition of equilibrium with respect to management is $CPY=W_M M$ where $P$ is the price of the product and $W_M$ is the wage of management. Under conditions of constant returns to scale we get: $(1-\sum_j B_j)PY=W_M M$. If the firms are also at their equilibrium point we get: $W_M M=PY-\sum_j W_j X_j$. Hence, the value of the marginal product is equal to that part of the total value product which was not imputed to other factors. That suggests that one can get an estimate of that value under the assumptions made above by simply substracting the distributive shares of all the other factors. This is very similar to the procedure suggested by Klein for estimating the production elasticities, except that we cannot do it directly and therefore must employ the assumption of constant returns to scale.[14] Klein's estimate for the elasticity of factor $j$ is

$$\hat{B}_j = \frac{\overline{X}_j \overline{W}_j}{\overline{Y}\overline{P}}$$

which is the proportion of the total product used as payment to factor $j$, evaluated at the point of geometric means. Our suggestion is to use (10) as before in order to estimate $C$.

This approach requires two assumptions: (a) Constant returns to scale; (b) That the firms are found at their equilibrium, apart from random variations. The first assumption is only necessary for estimating $C$ and was also used in the first approach introduced in this paper. The second assumption is necessary for estimating the other elasticities. It restricts the analysis and at first sight gives it a sense of being unrealistic. Against this limitation the equilibrium approach is attractive for the following reasons: (a) It is now immaterial whether management includes a farm effect or not. The results are not affected: (b) We do not need more than one observation per firm. Consequently, there is no need to assume that management remains constant over time. These two properties stem from the fact that in equilibrium the firm equates the relative share of the factor with the elasticity. As long as the elasticity remains constant the relative share is invariant to changes in the level of the function which are due to either time or firm effect. Such changes have their influence on the level of inputs and output. We are only concerned however with the relative share.

It seems that the strong properties of the equilibrium approach justify

[14] Klein, Lawrence R., *A Textbook of Econometrics* (Row, Peterson & Co., 1953), pp. 193–94.

some empirical analyses which will make it possible to compare results with those obtained by the use of the first approach. The equilibrium estimates for our study are reported in line (6) of Table 1. It is seen that the results are very close to the values obtained for the unrestricted equation, and thus are somewhat different from the results of the other equations. The sum of the elasticities is .828 which, under the assumption of constant returns to scale, yields an estimate of .172 for the elasticity of management. Hoch also reported estimates obtained by Klein's method. He obtained for the two respective quantities values of .751 and .249. The first estimate for the management elasticity was .406. The second one is not as high and may perhaps be nearer to the true one. But even if the first value is the "true" one, the equilibrium approach is a step in the right direction. The fact is that the two approaches require their own assumptions and it is difficult to judge a priori which set of assumptions is more realistic.

## *Concluding Remarks*

It has been demonstrated how to obtain regression coefficients of production functions that are free of management bias. This only solves one aspect of the problem of handling the management variable in the analysis of factor productivity. It does not solve the problem of estimating the conditional expectation of output for a given bundle of resources. The value to be estimated depends on the value of management and thus varies from firm to firm. The question is for what level of management such an estimate is to be made.

In most cases it is likely that such a question cannot be answered. As long as management is not measurable it is impossible to determine beforehand the level of management for which such an estimate is desirable. This problem also exists in computing the marginal productivities in the case of the Cobb Douglas function where the values are obtained by multiplying the elasticities by the average productivities. The average productivity depends on the level of management. One possibility is to ignore the management variable, in which case the inference will be directed to the average firm since it was assumed that the management variable in the sample is measured from its average.

A better possibility is to utilize the fact that management is correlated with other inputs. Such correlations are reflected in the interfirm regression. It is then preferable to use the interfirm function, because of the fact that it is subject to management bias, for the purpose of inferring about the productivity of a firm whose level of management is not known. This has been shown more formally and will not be reproduced here. It is only mentioned here to call attention to the fact that an unbiased equation is not necessarily better than a biased one for all purposes.

# APPROXIMATE AND EXACT SOLUTION TO NON-LINEAR PROGRAMMING PROBLEM WITH SEPARABLE OBJECTIVE FUNCTION*

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NON-LINEAR programming, if reasonably simplified from the computational standpoint, may become a useful tool in planning of production, when the decision-making unit faces product markets with negatively sloping demand curves.

The interest in non-linear programming is almost as old as in its linear correspondent. In 1951 Kuhn and Tucker explored the properties of solutions of non-linear programming problems.[1] Dorfman outlined the solution approach to a problem with negatively sloped, linear demand functions and independent activities, and to a quadratic programming problem with dependent activities.[2] Quadratic programming was further explored by Barankin and Dorfman, Hartley, and Wolfe.[3] However, quadratic programming is probably of limited use to economic problems. Charnes and Lemke extended non-linear programming to a much wider category of problems with separable convex functionals, by applying linear piecewise approximations to the (separable) components of the objective function.[4] Hartley modified the approach of linear piecewise approximation to separable convex functionals to problems with non-linear constraints.[5] Hartley also discussed the steps for simplifying the computations involved.

In this paper we present a new approach to the solution of a non-linear programming problem with separable objective function, where some (or all) of the products involved in planning are subject to negatively sloped, continuous demand functions.

The main feature of the suggested approach may be sketched out briefly before the detailed presentation: We consider for each "monopolized" activity its marginal net revenue function, which is approximated by a step-

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[1] Kuhn, H. W. and Tucker, A. W., "Non-linear programming," in Neyman, J., ed., *Second Berkeley Symposium on Mathematical Statistics and Probability,* Univ. Calif. Press, 1951.

[2] Dorfman, R., *Application of Linear Programming to the Theory of the Firm.* Univ. Calif. Press, 1951.

[3] See Barankin, E. W., and Dorfman, R., *On Quadratic Programming,* Univ. Calif. Publ. in Statistics, 1958; Hartley, H. O., *Non-Linear Programming for Separable Objective Functions and Constraints,* Iowa State Univ., mimeo, 1959; and Wolfe, P., "The Simplex Method for Quadratic Programming," *Econometrica,* Vol. XXVII, 1959.

[4] Charnes, A., and Lemke, C. E., "Minimization of Non-Linear Separable Convex Functionals," *Naval Research Quarterly,* Vol. 1., 1954.

[5] Hartley, *op cit.*

wise approximation. (The term "monopolized" is used as a simplification of an expression for a much wider category of all products with negatively sloping demand curves. Thus, the term applies both to products produced by monopolistic firms and to aggregate production by competitive firms as, e.g., in problems arising in regional or national production planning.) Each step or segment of the net revenue schedule is considered as a distinct subactivity.

The problem set in this manner is easily solved by the standard simplex method. The simplex solution may be brought to any desired degree of precision by successive stepwise approximations of the relevant range of the net revenue function. Furthermore, the approximate solution may be used to reformulate the problem towards finding the exact solution by a system of equations.

### *Formulation of the Problem*

The problem of non-linear programming with separable objective function and linear constraints considered in this paper may be formulated as follows: The goal is to maximize the profit function:

$$f = \sum_{j=1}^{n} c_j x_j \qquad (j = 1, 2, \cdots, n) \tag{1}$$

where some of the $c_j$'s, the net income per unit of the $j$th activity, are non-linear functions of the corresponding quantities $x_j$:

$$c_j = g_j(x_j) \tag{2}$$

The objective function is assumed to be separable in the sense that each of its components depends only on one of the $x_j$'s. Some of the $g_j(x_j)$ functions may be constants. Otherwise, they are (by assumption) continuously decreasing functions in the $x_j$'s. It is obvious that if all $c_j$'s are constants, i.e. if:

$$c_j = k_j \qquad \text{for all } j \tag{3}$$

where $k_j$ is a constant revenue regardless of output, the problem is reduced to one of linear programming.

Furthermore, the maximization is subject to a set of linear constraints:

$$\begin{aligned} \sum_{j=1}^{n} a_{ij} x_j &\leq b_i \qquad (i = 1, 2, \cdots, m) \\ x_j &\geq 0 \qquad (j = 1, 2, \cdots, n) \end{aligned} \tag{4}$$

We first assume: (a) constant coefficients of production (constant $a_{ij}$'s) for each activity, independent of its level, and (b) technical independence of the individual activities. We also assume that (c) the product

$x_j[g_j(x_j)]$ is differentiable with respect to $x_j$ and its derivative is either a constant or a positive, continuously decreasing function in $x_j$. The derivative

$$\frac{d}{dx_j}\,[x_j[g_j(x_j)]]$$

is easily identified as the marginal net revenue of the $j$th activity. The implications and possible modifications of the assumptions will be discussed in a later section. In particular, the modification of the assumption of constant input coefficients will be shown.

### *Definition of Set of Subactivities of a Parent Activity Producing a Monopolized Product*

We face a problem of planning the production level of activities, some of which produce monopolized products, subject to restrictions (4). For any activity, $k$, involved in production of a monopolized product we derive its net revenue function. Given a market demand function for product $k$ and the total cost (of production) function, the marginal net revenue, $MNR_k$, is the difference between the marginal gross revenue, $MR_k$, and the marginal cost, $MC_k$:

$$MNR_k = MR_k - MC_k \tag{5}$$

The marginal net revenue function is approximated, say, by $r$ "steps" or segments. Such a stepwise approximation to a hypothetical marginal net revenue function is shown in figure 1.

As shown in figure 1 the stepped net revenue function is bounded from outside by the corresponding continuous function. Thus, the net revenue over the whole quantity segment from any $q_t$ to $q_{t+1}$ is that corresponding to the quantity level $q_{t+1}$. Each segment of the stepped net revenue function is considered as a distinct subactivity of the parent activitity $k$, an activity with a downward sloping continuous demand function. The $r$ subactivities of the same parent activity have the same input coefficients (by assumption) but have different marginal net revenue. Each subactivity of the set (i.e. each segment of the marginal net revenue curve) corresponds to a given level of output of activity $k$.

### *The Approximate Solution*

In the preceeding section we have shown how each of the monopolized activities is partitioned into a set of subactivities, each subactivity corresponding to a given level of production of the parent activity, and a given marginal net revenue.

The subactivities of the same set have a property which is essential to

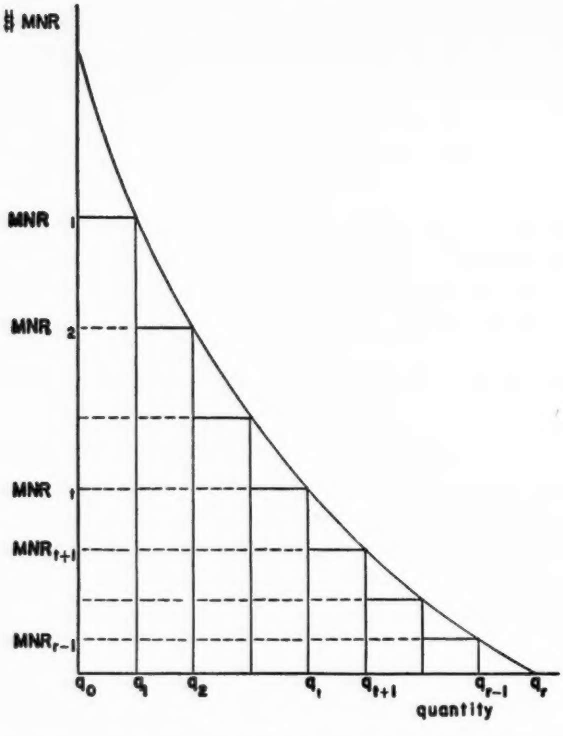


FIG. 1. STEPWISE APPROXIMATION TO A MARGINAL NET REVENUE FUNCTION.

our approach. The subactivities with higher marginal net revenue dominate the subactivities of the same set with lower marginal net revenue.[6] Namely,

$$\frac{MNR_{kt}}{a_{ikt}} > \frac{MNR_{k(t+1)}}{a_{ik(t+1)}} \tag{6}$$

where $MNR_{kt}$ is the marginal net revenue of the $t$th subactivity of the $k$th activity and $a_{ikt}$ is the $i$th input coefficient per unit of the $kt$th subactivity.

Relation (6) is obvious since $a_{ikt} = a_{ik(t+1)}$ by assumption of constant coefficients and $MNR_{kt} > MNR_{k(t+1)}$ due to decreasing marginal net revenue. Due to property (6) the subactivities of the same set will enter into the plan successively according to their decreasing marginal net revenue.

If we set proper quantity restrictions in the $B$ vector—i.e., augment the vector of real restrictions given in (4)—and set coefficients of one in the corresponding position in the subactivities' vectors, the correspondence between the quantity level and the marginal net revenue of each subac-

[6] For more details on the concept of dominance among activities in linear programming the interested reader may refer to Heady, E. O. and Candler W., *Linear Programming Methods*. Iowa State College Press, 1958, pp. 161–64.

tivity will be preserved. The restrictions vector $S$ and the $r$ subactivity vectors $P_k^1, P_k^2, \cdots, P_k^r$ of a monopolized activity $k$ are shown below:

$$(7)\quad S = \begin{bmatrix} B \\ q_1 - q_0 \\ q_2 - q_1 \\ q_3 - q_2 \\ \cdot \\ \cdot \\ \cdot \\ q_r - q_{r-1} \end{bmatrix} \qquad P_k^1 = \begin{bmatrix} A \\ 1 \\ 0 \\ 0 \\ \cdot \\ \cdot \\ \cdot \\ 0 \end{bmatrix}, \quad P_k^2 = \begin{bmatrix} A \\ 0 \\ 1 \\ 0 \\ \cdot \\ \cdot \\ \cdot \\ 0 \end{bmatrix}, \cdots, P_k^r = \begin{bmatrix} A \\ 0 \\ 0 \\ 0 \\ \cdot \\ \cdot \\ \cdot \\ 1 \end{bmatrix}$$

$B$, which is a part of the augmented restrictions vector $S$, is an $m$-column vector, the elements of which are the real restrictions $b_i$ given in (4) in the formulation of the problem. The remaining elements of $S$ are $r$ quantity restrictions imposed on the subactivities of $k$.

$A$, in the subactivities' vectors, is an $m$-column vector of real input coefficients $a_{ik}(i=1, 2, \cdots, m)$ given in (4). The remaining coefficients in these vectors are 1 and 0, which provide the correspondence between the relevant subactivitity and the level of output of the activity $k$. The values of $(q_1-q_0)$, $(q_2-q_1)$, $\cdots$, $(q_r-q_{r-1})$ and the marginal net revenues corresponding to the subactivities are taken from the stepwise approximation of the marginal net revenue function, as presented in figure 1.

For each additional set of subactivities of a monopolized activity, similar additions of restrictions to the $B$ vector should be performed. In general, each segment of a monopolized activity implies addition of one restriction to the restrictions vector. The detailed arrangement of the simplex table is illustrated by means of a numerical example in a later section.

Finally the original objective function is reformulated in order to conform to the discrete modification of the problem. Assuming that the first $p(p<n)$ activities represent monopolized products, the others being competitive, the objective function (1) may be written:

$$f = \sum_{j=1}^{p} x_j[g_j(x_j)] + \sum_{j=p+1}^{n} c_j x_j$$

We rewrite the above:

$$(8)\qquad f = \sum_{j=1}^{p} \int_0^{x_j} \frac{d}{dx_j}\,[x_j[g_j(x_j)]]dx_j + \sum_{j=p+1}^{n} c_j x_j$$

where

$$\frac{d}{dx_j}\,[x_j[g_j(x_j)]]$$

is the marginal net revenue of the $j$th activity and its integral over the range of $x_j$ is the corresponding total revenue. Using the discrete approximation and recalling that $x_j \geq 0$ for all $j$, we get for $f$:

$$f = \sum_t MNR_{1t}(q_{1t} - q_{1(t-1)}) + \sum_t MNR_{2t}(q_{2t} - q_{2(t-1)}) + \cdots$$
(9)
$$+ \sum_t MNR_{pt}(q_{pt} - q_{p(t-1)}) + \sum_{j=p+1}^{n} c_j x_j$$

where the subscript $t$ denotes the $t$th subactivity of any monopolized activity $j$ and the $x_j$'s with $j > p$ represent the competitive activities.

The above formulation of the subactivities and the modification of the objective function transforms the problem into one (a) equivalent to the marginal allocation problem known from basic economic theory and (b) easily solvable by the simplex method. Indeed the simplex procedure follows the marginal allocation principle. The resources are allocated step by step to those activities which provide the highest net revenue at each step, while the net revenue of each activity is discounted by its opportunity cost.

The modified objective function, which is equivalent to the original except for the discrete approximation introduced, is maximized subject to the real restrictions of (4) and the additional quantity restrictions imposed on the $x_{jt}$'s. The correct order of "entering into the program" in each set of subactivities is guaranteed by the fact that the subactivities with higher marginal net revenue dominate those with lower marginal net revenue. A later section presents the process of approximate solution for a simple numerical example.

### *The Exact Solution*

After derivation of the first approximate solution an improved approximation may be obtained by a more precise segmentation of the relevant part of the net revenue function, and by repetition of the simplex process.[7] For most practical purposes, a close approximation will be satisfactory. Obviously, by successive approximations, the solution may be brought to any desired degree of precision.

It should be noted that splitting the monopolized activities into numerous subactivities expands the size of the problem. If the problem expands to an unmanageable extent it is possible to reduce the number of subactivities in the first simplex (approximate) solution by partitioning the monopolized activities into fewer subactivities. The relevant range of the marginal net revenue function of each monopolized activity may be roughly identified by the first approximate solution. For the second simplex

[7] Actually only the last part of the first solution should be repeated.

solution we need to apply a more precise approximation of each marginal net revenue function in its relevant range only, i.e., in the neighborhood of the first approximate solution. The range of the marginal net revenue function to the right of the relevant range (the range with lower marginal net revenue values) becomes irrelevant, because the subactivities representing this range do not enter the optimal solution. The range of the marginal net revenue function on the left side of the relevant range (the range with higher marginal net revenue values) can be only roughly approximated because the subactivities representing this range will enter the optimal plan anyway. Hence, the number of subactivities in the second approximation need not be larger than that in the first approximation. Thus, it is possible to keep the size of the corresponding simplex tables within manageable limits by using a larger number of successive approximate simplex solutions.

On the basis of the approximate solution it is possible to reformulate the problem to one leading to a system of equations, and if these equations are easily solved, successive approximations may be avoided. The approximate solution shows which of the real restrictions of (4) are effective and which of the activities can enter the program. If this is known the problem may be converted into one of solving for a maximum subject to linear restraints. Suppose, for our problem, that the first $h$ activities enter the approximate solution and that they use the first $s$ restrictions. We form the Lagrangean expression:

$$F = \sum_{j=1}^{h} x_j[g_j(x_j)] - \sum_{i=1}^{s} \lambda_i \sum_{j=1}^{h} (a_{ij}x_j - b_i) \tag{10}$$

Taking the partial derivatives with respect to the $x_j$'s and $\lambda_i$'s and equating them to zero a system of $(h+s)$ equations with $(h+s)$ unknowns is obtained:

$$\begin{aligned} &\frac{\partial}{\partial x_j}[x_j[g_j(x_j)]] - \sum_{i=1}^{s} \lambda_i a_{ij} = 0 \qquad (j = 1, 2, \cdots, h) \\ &\sum_{i=1}^{h} a_{ij}x_j - b_i = 0 \qquad (i = 1, 2, \cdots, s) \end{aligned} \tag{11}$$

The left term in the first $h$ equations (11) is the marginal net revenue of the $j$th activity. As has been shown by Samuelson,[8] the Lagrangean multipliers $\lambda_i$ are equivalent to the imputed values of the resources. Each resource which is not exhausted has an imputed value of zero and hence should not appear in expression (10). The last $s$ equations in (11) simply restate the condition that for the exhausted restrictions the sum of the inputs used should equal the total supply.

[8] Samuelson, P. A., *Foundations of Economic Analysis*, Harvard Univ. Press, 1947, chap. 4.

The possibility of obtaining the exact solution in this way depends, of course, on the mathematical form of the first $h$ equations in (11).[9]

It may occur that the simplex solution, by its approximate nature allowing for some error, will lead to an erroneous formulation of the Lagrangean expression (10). In other words, it may occur that the exact solution obtained through (10) and (11) will be inconsistent with the assumptions made in formulation of (10) with respect to the effective restrictions and the activities used. For example, one of the restrictions assumed ineffective and hence not included in (10) may become "overused" by the solution of (11). Or, an activity assumed not to be in the program in the formulation of (10) may become profitable and relevant for activation. These inconsistencies may occur if rough approximations are applied in the simplex solution, and significant changes are involved in a shift to the exact solution.

To check that the exact solution does not violate any of the real restrictions (4) not included in the Lagrangean expression (10), we test the validity of:

$$\sum_{j=1}^{h} a_{ij}x_j \leq b_i \quad (i = s+1, s+2, \cdots, m) \tag{12}$$

Also, it is necessary to consider the justification of elimination of the $(n-h)$ activities which were not included in the formulation of (10). To this goal we make use of some properties of the solution of a non-linear programming problem which were investigated by Kuhn and Tucker.[10] The economic interpretation of the findings of Kuhn and Tucker is given by Dorfman,[11] and by Dorfman, Samuelson and Solow.[12] Omitting the proofs, which may be found in the above references, we restate the following theorem from Drofman *et al.*[13]

If a certain program $x_1^0, x_2^0, \cdots, x_n^0$ maximizes an objective function

$$f = \sum_{j=1}^{n} x_j[g_j(x_j)]$$

subject to restrictions (4), then there must exist some non-negative numbers $\lambda_1, \lambda_2, \cdots, \lambda_m$ such that for all values of $j$ $(j=1, 2, \cdots, n)$ either:

$$x_j^0 = 0 \text{ (activity } j \text{ is not used) and } \frac{\partial f}{\partial x_j} - \sum_{i=1}^{m} a_{ij}\lambda_i \leq 0 \tag{13}$$

or

$$x_j^0 > 0 \text{ (activity } j \text{ is used) and } \frac{\partial f}{\partial x_j} - \sum_{i=1}^{m} a_{ij}\lambda_i = 0 \tag{14}$$

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[9] If only one real restriction is exhausted, the exact solution may be easily derived by an iterative procedure for any mathematical functions.

[10] Kuhn and Tucker, *op. cit.*

[11] Dorfman, *Application of Linear Programming . . .*, *op. cit.*

[12] Dorfman, R., Samuelson, P. A., and Solow, R. M., *Linear Programming and Economic Analysis*, McGraw-Hill, New York, 1958, p. 193.

[13] Dorfman *et al.*, *ibid.*

We note that $\partial f/\partial x_j$ is the marginal net revenue of the $j$th activity while $\lambda_i$ is the imputed value per unit of the $i$th resource. In economic terms, (13) and (14) state that for any activity not used, the marginal net revenue per activity unit is smaller than or equal to the imputed marginal cost; and that for any activity used the marginal net revenue is equal to the imputed marginal cost.

To check whether the exact values of the $\lambda_i$'s derived in the solution of (11) do not imply inclusion of additional activities not included in (10) and (11) we test the validity of:

$$\frac{\partial f}{\partial x_j} - \sum_{i=1}^{s} a_{ij}\lambda_i \leq 0 \quad (j = h+1, h+2, \cdots, n) \tag{15}$$

If relations (12) and (15) are satisfied, the exact solution prevails. Violation of one of the relations (12) or (15) implies that the assumptions in formulation of (10) were incorrect. In this case a closer approximation to the exact solution should be sought through the simplex procedure.

### *The Number of Real Constraints Used in the Optimal Program*

It is of interest to consider the situations arising in solutions of non-linear problems with respect to the number of constraints used. We consider first a firm which produces monopolized products only.[14] One of the two following situations may arise: (1) The maximum net revenue is attained within the boundary of the convex polyhedron generated by the real constraints (4), i.e., none of the restrictions is exhausted. In this case no programming is involved and the problem becomes trivial. To find the maximum total net revenue we have to maximize independently the total net revenue for each activity, i.e., extend its output up to the level at which the marginal net revenue is zero. Hence, facing a problem of non-linear programming with monopolized activities only, and having reason to suspect that excess capacity exists, we will find it advisable to compute directly the maximal net revenue solution and to check whether it is feasible. A case of a monopolistic firm with excess capacity may provide an example for this situation.[15] (2) If the unrestricted maximum net revenue point lies outside of the feasible convex polyhedron, it is unattainable, and the level of one or more activities should be decreased. Obviously, in a case where no excess capacity exists the solution lies on the boundary of the convex polyhedron.

In linear programming the solution always lies on one of the extreme points of the convex polyhedron. However, in the non-linear case the solution may fall on any point of the boundary, as a result of the non-linear

[14] The term "firm" is used in its widest sense as an effective decision-making unit.

[15] Or, assume that one is assigned a task of finding the optimal output of U.S. agriculture, with the goal of maximizing the total net revenue of the producers. Guessing that excess capacity exists, we can try to estimate the optimal outputs for each agricultural industry ignoring the restrictions.

shape of the relevant isorevenue functions. Hence, if only monopolized activities are involved in a programming problem, there is reason to expect that fewer restrictions will be exhausted, in comparison with a similar problem with competitive activities and constant prices. Computational work may be lessened accordingly. (3) Finally, consider a firm producing both monopolized and competitive products. The solution will always be on the boundary of the convex polyhedron. Each competitive activity introduced into the program will "consume" one restriction as in the case of linear programming, and for the same reason.

If, as we assumed, in the final solution there are $p$ monopolized activities which may possibly not "consume" any one of the $m$ real restrictions, the maximal number of activities in the optimal program may be $(p+m)$, i.e., the number of monopolized products plus the number of real restrictions. On the other hand, the minimum number of activities in the optimal program is one. One activity only in the solution will occur when a single activity consumes completely one of the restrictions which is essential to production of each of the other activities.

### *A Numerical Example*

We consider a highly simplified example concerned with two monopolized activities (1 and 2) and two competitive activities (3 and 4). The average and the marginal net revenue schedules are as follows:

| *Activity number* | *Activity level* | *Average net revenue function* | *Marginal net revenue function* |
|---|---|---|---|
| 1 | $x_1$ | $120 - \dfrac{x_1}{10}$ | $120 - \dfrac{x_1}{5}$ |
| 2 | $x_2$ | $90 - \dfrac{x_2}{20}$ | $90 - \dfrac{x_2}{10}$ |
| 3 | $x_3$ | 75 | 75 |
| 4 | $x_4$ | 100 | 100 |

The problem is to maximize

$$f = x_1\left(120 - \frac{x_1}{10}\right) + x_2\left(90 - \frac{x_2}{20}\right) + 75x_3 + 100x_4 \tag{16}$$

subject to

$$3x_1 + 4x_2 + 2x_3 + x_4 \leq 2500 \tag{17}$$

$$x_1 + x_2 + x_3 + 2x_4 \leq 700 \tag{18}$$

and

$$x_1 \geq 0; \quad x_2 \geq 0; \quad x_3 \geq 0; \quad x_4 \geq 0. \tag{19}$$

On the basis of the marginal net revenue functions for the two monopolized activities we define the corresponding subactivities. The specification of the subactivities and of "linear" activities 3 and 4 is shown in table 1.

It is easily seen that subactivities $P_1^3$ through $P_1^6$ and $P_2^2$ through $P_2^9$ are dominated by activity $P_3$. Thus the set of "real" vectors which need to be included in the simplex table is reduced to five: $P_1^1$, $P_1^2$, $P_2^1$, $P_3$ and $P_4$.

The simplex table and the solution process are presented in table 2.

Considering Section I of the simplex tableau of table 2, $P_1^1$ and $P_1^2$ are the relevant subactivities (those not dominated by activity $P_3$) of the first monopolized product; $P_2^1$ is the relevant subactivity of the second monopolized product. $P_3$ and $P_4$ represent the two competitive products. In the $P_0$ vector, $P_5$ and $P_6$ represent the real restrictions, while $P_7^1$, $P_7^2$ and $P_8^1$ are the quantity restrictions imposed on the monopolized activities. The solution proceeds along the standard simplex path. We note that in passing from Section I to Section II of table 2 three activities are introduced simultaneously into the "basis" (as a short cut in the computations). The approximate solution is arrived at in Section III. It is: 200 units of $P_1$, 100 units of $P_2$ and 400 units of $P_3$. Activity $P_4$ is not used. Only one real restriction, $P_6$, is exhausted.

The approximate solution may be brought to a greater degreee of precision by more precise approximation of the net revenue functions. However, we prefer to speed up a bit with an attempt for the exact solution. On the basis of the approximate solution, which shows us which activities are in the plan and which restrictions are exhausted, we form the following Lagrangean expression:

$$F = x_1\left(120 - \frac{x_1}{10}\right) + x_2\left(90 - \frac{x_2}{20}\right) + 75x_3 - \lambda(x_1 + x_2 + x_3 - 700) \tag{20}$$

Differentiating (20) successively with respect to the unknowns and equating to zero we get:

$$\begin{aligned} \frac{\partial F}{\partial x_1} &= 120 - \frac{1}{5}x_1 - \lambda = 0 \\ \frac{\partial F}{\partial x_2} &= 90 - \frac{1}{10}x_2 - \lambda = 0 \\ \frac{\partial F}{\partial x_3} &= 75 - \lambda = 0 \\ \frac{\partial F}{\partial \lambda} &= -x_1 - x_2 - x_3 + 700 = 0 \end{aligned} \tag{21}$$

From (21) we derive $x_1=225$; $x_2=150$; $x_3=325$; and $\lambda=75$.

TABLE 1. SPECIFICATION OF SUBACTIVITIES OF MONOPOLIZED PRODUCTS AND OF COMPETITIVE ACTIVITIES

| Activity Number | Monopolized Activities | | | | | | | | | | | | | | | Competitive Activities | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | | | | | | 2 | | | | | | | | | 3 | 4 |
| Symbol | $P_1^1$ | $P_1^2$ | $P_1^3$ | $P_1^4$ | $P_1^5$ | $P_1^6$ | $P_2^1$ | $P_2^2$ | $P_2^3$ | $P_2^4$ | $P_2^5$ | $P_2^6$ | $P_2^7$ | $P_2^8$ | $P_2^9$ | $P_3$ | $P_4$ |
| Level of activity | 0–100 | 100–200 | 200–300 | 300–400 | 400–500 | 500–600 | 0–100 | 100–200 | 200–300 | 300–400 | 400–500 | 500–600 | 600–700 | 700–800 | 800–900 | 0–∞ | 0–∞ |
| Marginal net revenue | 100 | 80 | 60 | 40 | 20 | 0 | 80 | 70 | 60 | 50 | 40 | 30 | 20 | 10 | 0 | 75 | 100 |
| Input coefficients | 3<br>1 | 3<br>1 | 3<br>1 | 3<br>1 | 3<br>1 | 3<br>1 | 4<br>1 | 4<br>1 | 4<br>1 | 4<br>1 | 4<br>1 | 4<br>1 | 4<br>1 | 4<br>1 | 4<br>1 | 2<br>1 | 1<br>2 |

TABLE 2. THE SIMPLEX SOLUTION

| | $c_j \rightarrow$ | | | | | | | | 100 | 80 | 80 | 75 | 100 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $\downarrow$ | $P_j$ | $P_0$ | $P_5$ | $P_6$ | $P_7^1$ | $P_7^2$ | $P_8^1$ | $P_1^1$ | $P_1^2$ | $P_2^1$ | $P_3$ | $P_4$ |
| | | $P_5$ | 2,500 | 1 | | | | | 3 | 3 | 4 | 2 | 1 |
| | | $P_6$ | 700 | | 1 | | | | 1 | 1 | 1 | 1 | 2 |
| | $\leftarrow$ | $P_7^1$ | 100 | | | 1 | | | 1 | | | | |
| Section I | $\leftarrow$ | $P_7^2$ | 100 | | | | 1 | | | 1 | | | |
| | $\leftarrow$ | $P_8^1$ | 100 | | | | | 1 | | | 1 | | |
| | | $Z_j$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | $Z_j-c_j$ | 0 | 0 | 0 | 0 | 0 | 0 | −100 | −80 | −80 | −75 | −100 |
| | | $P_5$ | 1,500 | 1 | | − 3 | − 3 | − 4 | | | | 2 | 1 |
| | $\leftarrow$ | $P_6$ | 400 | | 1 | − 1 | − 1 | − 1 | | | | 1 | 2 |
| $\rightarrow$ | 100 | $P_1^1$ | 100 | | | 1 | | | 1 | | | | |
| Section II $\rightarrow$ | 80 | $P_1^2$ | 100 | | | | 1 | | | 1 | | | |
| $\rightarrow$ | 80 | $P_2^1$ | 100 | | | | | 1 | | | 1 | | |
| | | $Z_j$ | 26,000 | 0 | 0 | 100 | 80 | 80 | 100 | 80 | 80 | 0 | 0 |
| | | $Z_j-c_j$ | 26,000 | 0 | 0 | 100 | 80 | 80 | 0 | 0 | 0 | −75 | −100 |
| | | $P_5$ | 700 | 1 | − 2 | − 1 | − 1 | − 2 | | | | | − 3 |
| $\rightarrow$ | 75 | $P_3$ | 400 | 0 | 1 | − 1 | − 1 | − 1 | | | | 1 | 2 |
| | 100 | $P_1^1$ | 100 | | | 1 | | | 1 | | | | |
| | 80 | $P_1^2$ | 100 | | | | 1 | | | 1 | | | |
| Section III | 80 | $P_2^1$ | 100 | | | | | 1 | | | 1 | | |
| | | $Z_j$ | 56,000 | 0 | 75 | 25 | 5 | 5 | 100 | 80 | 80 | 75 | 150 |
| | | $Z_j-c_j$ | 56,000 | 0 | 75 | 25 | 5 | 5 | 0 | 0 | 0 | 0 | 50 |

The second derivatives with respect to $x_1$ and $x_2$ are negative, hence the solutions indicate maxima. Also, since only one solution exists, it indicates the over-all maximum. $\lambda$ is the imputed value of one unit of the $P_6$ resource. The imputed value of $P_5$ is zero.

Finally we perform the checks indicated in (12) and (15). For (12) we get numerically:

$$3 \cdot 225 + 4 \cdot 150 + 2 \cdot 325 = 1925 < 2500 \tag{22}$$

or: Input of the $P_5$ resource is less than the supply of this resource. For (15) we have numerically:

$$0 \cdot 1 + 75 \cdot 2 = 150 > 100 \tag{23}$$

or: The imputed cost of activity $P_4$ is less than the net revenue of activity $P_4$. Since the relations (12) and (15) hold, the exact solution is accepted.

### *The Nature and Modifications of the Assumptions*

An initial assumption was made with respect to the marginal net revenue function: namely, that it was a continuously decreasing function of the quantity produced. As is well known, a marginal (gross) revenue function corresponding to a continuously decreasing demand function is itself a continuously decreasing function of the quantity produced. It may be shown easily that under conditions of constant and rising marginal costs the marginal net revenue function, derived as a difference between the marginal gross revenue and marginal cost, is itself a continuously decreasing function. The same will be true for the case of falling marginal costs if the marginal

cost function falls less rapidly than marginal gross revenue function. Only if the marginal cost function falls more rapidly than the marginal gross revenue function will the slope of the marginal net revenue function be positive. The last situation cannot be handled with our approach. (The reader should note that constant marginal costs are consistent with constant input coefficients, unless pecuniary economies or diseconomies of scale exist.) The assumption of continuity of the marginal net revenue function requires continuity in the demand function, i.e., kinked demand functions are excluded unless the approach is modified.

The assumption of constant input coefficients previously made now may be replaced with a less restrictive condition. The necessary and sufficient condition for success of our approach is that for subactivities of the same monopolized product, *the subactivities with higher marginal net revenue will dominate the subactivities with lower marginal net revenue.* This condition will be met in situations of decreasing productivity, and to some extent in situations of increasing productivity, as far as increasing resource productivity is more than offset by the decreasing marginal revenue. It is only necessary, in the case of varying input coefficients, that they be stated in the marginal manner. For any subactivity referring to a given production level, we must specify the additional inputs required to produce the additional product. It should be pointed out, however, that in the case of variable input coefficients, non-linear terms in the $\lambda_i$ in the first $h$ equations (11) are introduced. As a result, the exact solution procedure may become more complicated.

Further study is needed to overcome the restrictions imposed by the assumption of separable objective function. Alternatively, it may be useful to evaluate empirically the implications arising from this assumption. Some empirically derived demand functions have been statistically explained, without including variables for related commodities in the function.[16] However, a minority of cases may be so represented. For practical purposes, it would be important to evaluate the biases involved in neglecting the related commodities or cross elesticities in the demand function. On the basis of such information it will be possible to decide, in each concrete case, on the practical justification of the assumption of a separable objective function for the various products. For other variables included in the demand function (such as income, population, etc.), relevant values may be "plugged into" the demand functions with these variables considered to be exogenous.

[16] For example, in Fox, K. A , *The Analysis of Demand for Farm Products,* U.S.D.A. Tech. Bul. 1081; demand for pork, p. 43; for eggs, p. 52; for apples, peaches, cranberries, potatoes, sweet potatoes, onions, oranges, grapefruit and lemons, p. 65.

# THE EFFECTS OF AUTOCORRELATED ERRORS ON THE STATISTICAL ESTIMATION OF DISTRIBUTED LAG MODELS*

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RECENT economic literature has been invaded by the rapidly increasing use of distributed lag models as a tool for economic analysis.[1] These models have been used to estimate economic parameters such as the price and income elasticities of demand, the elasticity of supply, and the elasticity of adjustment for various commodities. Agricultural economists utilize these estimates in the evaluation of agricultural policies and programs. Hence, the properties of these estimates are of more than a little importance.

This paper considers the statistical estimation of such models and, in particular, the effect of autocorrelated errors upon the estimates. With the aid of empirical examples we shall (1) illustrate the nature of the bias in ordinary least squares estimates arising from autocorrelated errors, (2) present a method of estimation yielding consistent estimates for the parameters of an equation containing autocorrelated errors, (3) demonstrate the low power of the Durbin-Watson statistic when applied to the residuals of an equation containing the lagged endogenous variable, and (4) present a method for computing confidence limits for the estimated long-run elasticities.

## *The Economic Model*[2]

For this investigation the following economic model is specified:

$$Y_t^* = a_0 + a_1 X_{1t} + a_2 X_{2t} \tag{1}$$

$$Y_t - Y_{t-1} = \gamma(Y_t^* - Y_{t-1}) \qquad 0 < \gamma < 2 \tag{2}$$

where $Y_t^*$ is the "equilibrium" quantity of a commodity that would be demanded at time $t$ for a given price, $X_{1t}$, and income, $X_{2t}$. $Y_t$ is the actual quantity demanded, and $\gamma$ is the elasticity of adjustment. The equations

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[1] For detailed discussions of models of this type see Marc Nerlove, *Distributed Lags and Demand Analysis for Agricultural and Other Commodities*, Agr. Mktg. Serv., USDA, Agr. Hb. No. 141, Washington, June 1958.

[2] Marc Nerlove and William Addison, "Statistical Estimation of Long-Run Elasticities of Supply and Demand," *J. Farm Econ.* 50:868, Nov. 1958.

are assumed to be linear in logarithms. Thus, $a_1$ and $a_2$ may be interpreted as the long-run price and income elasticities. Substituting equation (1) into (2) and solving for $Y_t$ results in:

$$(3) \qquad Y_t = a_0\gamma + a_1\gamma X_{1t} + a_2\gamma X_{2t} + (1-\gamma)Y_{t-1}$$

where $a_1\gamma$ and $a_2\gamma$ may be interpreted as the short-run price and income elasticities.

*Error Models and Estimation*

A not uncommon practice following the derivation of equation (3) is to add an error term, giving:

$$(3a) \qquad Y_t = a_0\gamma + a_1\gamma X_{1t} + a_2\gamma X_{2t} + (1-\gamma)Y_{t-1} + u_t$$

and to estimate the coefficients by least squares. The regression coefficient obtained for $Y_{t-1}$ furnishes an estimate of $(1-\gamma)$ and hence of $\gamma$. Estimates of the parameters $a_1$ and $a_2$ are then obtained by dividing the regression coefficient of $X_{1t}$ and $X_{2t}$ by the estimate of $\gamma$. Provided that the errors, $u_t$, are non-autocorrelated, such a procedure yields consistent[3] estimates of the parameters. However, if the errors are autocorrelated the least-squares estimates of the parameters may be seriously biased even in large samples.[4]

The nature of economic time series casts doubt on the reasonableness of the assumption of nonautocorrelated errors. Cochran and Orcutt[5] list three reasons for expecting autocorrelation in the errors: (1) given autocorrelated series the choice of an incorrect functional form will result in autocorrelated errors; (2) errors arising from the omission of economic and noneconomic variables will tend to be autocorrelated, as the omitted variables are generally autocorrelated; (3) errors of measurement present in the data are often autocorrelated.

This paper, therefore, suggests the use of a less restrictive error model. The assumption that the $u_t$ are non-autocorrelated is replaced by the assumption that the $u_t$ follow a first order autoregressive scheme,[6] i.e.,

$$(4) \qquad u_t = \beta u_{t-1} + \epsilon_t \qquad -1 < \beta < 1$$

where it is now assumed that the $\epsilon_t$ are non-autocorrelated, of constant

[3] The estimates are not unbiased. Hurwicz has demonstrated that the least-squares estimates of the coefficients of auto-regressive equations (equations utilizing the lagged endogenous variable as an explanatory variable) are biased in small samples. Leonid Hurwicz, "Least-Squares Bias in Time Series," *Cowles Com. Mono. 10*, New York, Wiley, 1950.

[4] See L. M Koyck, *Distributed Lags and Investment Analysis*, Amsterdam, Netherlands, North Holland Pub. Co., 1954, p. 32, and Wayne A. Fuller, "Autocorrelated Errors and the Estimation of Distributed Lag Models," unpub. ms., Iowa State Univ , 1959.

[5] D. Cochran and G. H. Orcutt, "Application of Least Squares Regression to Relationships Containing Autocorrelated Error Terms," *J. Amer. Stat. Assoc.*, 44:36–61, 1949.

[6] Note that the method of estimation suggested later may be used for error specifications of second and higher degree auto-regressive schemes.

variance, and uncorrelated with the predetermined variables of the model, i.e.,

$$E(\epsilon_t\epsilon_{t-j}) = 0 \qquad j \neq 0 \tag{5}$$

$$E(\epsilon_t^2) = \sigma^2 \qquad \text{all } t \tag{6}$$

$$E(X_{it}\epsilon_t) = 0 \qquad \text{all } i \tag{7}$$

$$E(Y_{t-j}\epsilon_t) = 0 \qquad j \geq 1. \tag{8}$$

Solving equation (3a) for $u_t$ and lagging each variable one time period gives:

$$u_{t-1} = Y_{t-1} - a_0\gamma - a_1\gamma X_{1t} - a_2\gamma X_{2t} - (1 - \gamma)Y_{t-2}. \tag{9}$$

Substituting equation (9) into (4) yields:

$$u_t = \beta Y_{t-1} - a_0\gamma\beta - a_1\gamma\beta X_{1t} - a_2\gamma\beta X_{2t} - (1 - \gamma)\beta Y_{t-2} + \epsilon_t \tag{10}$$

and substituting from (10) into (3a) produces:

$$Y_t = b_0 + b_1X_{1t} + b_2X_{2t} + b_3Y_{t-1} + b_4X_{1t-1} + b_5X_{2t-1} + b_6Y_{t-2} + \epsilon_t \tag{11}$$

where:

$$\begin{aligned} &b_0 = a_0\gamma && \\ &b_1 = a_1\gamma && b_4 = -\,a_1\gamma\beta \\ &b_2 = a_2\gamma && b_5 = -\,a_2\gamma\beta \\ &b_3 = (1 - \gamma) + \beta && b_6 = -\,(1 - \gamma)\beta. \end{aligned} \tag{11a}$$

An inspection of equations (11) and (11a) indicates that if $\beta=0$, equation (11) reduces to the form of (3a). It is also apparent that if $\beta=0$ and $\gamma=1$, equation (11) reduces to the form of (1) and the long-run elasticities may be estimated directly from a static type analysis, i.e., the regression of price and income on quantity. If $\beta=1$ equation (11) reduces to an equation of the form (3a) where the variables are expressed in first differences.

The reader may also have noted that among the multiplicity of economic lag specifications there is one that would yield an equation containing the same variables as (11). Let it only be said that given the form of the economic model, the error specification (4) may be introduced and a reduction similar to (9)–(11) carried out.

The direct application of the method of least squares to equation (11) is possible, but will, in general, yield conflicting estimates of the original parameters. This becomes apparent when one observes that least squares will estimate seven parameters for (11) while the original model specified only five parameters, i.e., the system (11a) is composed of seven equations in five unknowns.

Therefore, the following iterative estimation procedure is suggested.[7] First, a beginning set of estimates is selected for the unknown parameters. It is suggested that this set be selected by inspecting the least-squares solution of equation (11) utilizing equations (11a). For convenience we introduce simplifying notation and indicate the beginning set of estimates by:

$$P_0 = (\theta_{10}, \theta_{20}, \theta_{30}, \theta_{40}) \tag{12}$$

where

$$\begin{aligned}\theta_1 &= a_1\gamma \\ \theta_2 &= a_2\gamma \\ \theta_3 &= (1-\gamma) \\ \theta_4 &= \beta\end{aligned}$$

and the subscript is used to denote the iteration number, 0 denoting the start values. Further, we assume that the variables are now expressed as deviations from their respective means so that we need now only concern ourselves with four parameters.[8]

Next, expand equation (11) about $P_0$ in a Taylor series retaining only the first order terms. This yields:

$$Y_t - Y_{t0} = Z_{10}\Delta\theta_{10} + Z_{20}\Delta\theta_{20} + Z_{30}\Delta\theta_{30} + Z_{40}\Delta\theta_{40} \tag{13}$$

where:

$$\begin{aligned}Y_{t0} &= \theta_{10}X_{1t} + \theta_{20}X_{2t} + (\theta_{30}+\theta_{40})Y_{t-1} - \theta_{10}\theta_{40}X_{1t-1} \\ &\quad - \theta_{20}\theta_{40}X_{2t-1} - \theta_{30}\theta_{40}Y_{t-2} \\ Z_{10} &= X_{1t} - \theta_{40}X_{1t-1} \\ Z_{20} &= X_{2t} - \theta_{40}X_{2t-1} \\ Z_{30} &= Y_{t-1} - \theta_{40}Y_{t-2} \\ Z_{40} &= Y_{t-1} - \theta_{10}X_{1t-1} - \theta_{20}X_{2t-1} - \theta_{30}Y_{t-2}.\end{aligned}$$

The $Z_{i0}$ are the first derivatives of equation (11) with respect to each unknown parameter, and the $\Delta\theta_{i0}$ are the deviations of the $\theta_{i0}$ from the true parameters. Now compute the regression of $Y_t - Y_{t0}$ on the $Z_{i0}$ to obtain estimates of the $\Delta\theta_{i0}$.[9]

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[7] This procedure is outlined in Wayne A. Fuller. *op. cit.* A description of the general approach is available in H. O. Hartley, "The Modified Gauss-Newton Method for Fitting of Non-Linear Regression Functions by Least Squares" (forthcoming in *Technometrica*).

[8] Once these four parameters are estimated, $b_0$ of equation (11) may be computed from:

$$b_0 = \bar{y}_t - \theta_1\bar{x}_{1t} + \theta_1\theta_4\bar{x}_{1t-1} - \theta_2\bar{x}_{2t} + \theta_2\theta_4\bar{x}_{2t-1} - (\theta_3+\theta_4)\bar{y}_{t-1} + \theta_3\theta_4\bar{y}_{t-2}$$

[9] A more detailed description of the procedure may be obtained from the authors upon request.

If the estimated $\Delta\theta_{i0}$ thus obtained are not small, the process is repeated using as the second start point:

$$P_1 = [(\theta_{10} + \Delta\hat{\theta}_{10}), (\theta_{20} + \Delta\hat{\theta}_{20}), (\theta_{30} + \Delta\hat{\theta}_{30}), (\theta_{40} + \Delta\hat{\theta}_{40})] \tag{14}$$

where the $\Delta\hat{\theta}_{i0}$ are the least-squares estimates of $\Delta\theta_{i0}$. Iteration is carried on until the $\Delta\hat{\theta}_{ij}$ become insignificantly small.

Assuming that the $X_{it}$ are bounded and the $\epsilon_t$ normally distributed, the final set of estimates, $P_j$, are maximum likelihood estimates possessing the properties of consistency and asymptotic normality. The large sample variances and covariances are estimated in the ordinary manner as the product of the elements, $c_{ij}$, of the $(ZZ')^{-1}$ matrix obtained at the final iteration and the estimated variance, $s^2$, where:

$$s^2 = \frac{\sum_t (y_t - \hat{y}_t)^2}{n - r} \tag{15}$$

where $n$ is the number of observations and $r$ is the number of parameters estimated (the model under consideration contains five parameters).

If the several estimates of $\beta$ computed from the initial least squares estimation of equation (11) are extremely divergent, one may have little confidence that the chosen start point is close to the true solution i.e., the point of the absolute minimum residual sum of squares. In such a case a second start point with the estimates of $\gamma$ and $\beta$ differing considerably from the first may be chosen and the iteration process repeated. If the procedure converges to a second set of estimates, a comparison of the residual sums of squares is made and the set of estimated parameters giving the smallest residual sum of squares is the maximum likelihood solution.

### *Confidence Intervals for the Estimated Long-Run Elasticities*

Since the estimates of the long-run elasticities are of interest, it is important to have available a measure of reliability for these estimates. Approximate confidence intervals for the long-run price elasticities were computed by noting that the equation giving the long-run price elasticity,

$$a_1 = \frac{\theta_1}{1 - \theta_3} \tag{16}$$

may also be written as,

$$\theta_1 - a_1(1 - \theta_3) = 0. \tag{17}$$

Thus, those values of $a_1$ such that:

$$p\left\{\frac{\{[\hat{\theta}_1 - a_1(1 - \hat{\theta}_3)] - 0\}^2}{s^2(c_{11} + 2a_1c_{13} + a_1^2c_{33})} \leq t_\alpha^2\right\} = 1 - \alpha \tag{18}$$

will define the $(1-\alpha)$ confidence interval for the estimate of $a_1$. Equation (18) reduces to a quadratic in $a_1$:

$$(18a)\quad p\{[(1-\theta_3)^2 - t_\alpha^2 s^2 c_{33}]a_1^2 - [2\theta_1(1-\theta_3) + 2t_\alpha^2 s^2 c_{13}]a_1 + [\theta_1^2 - t_\alpha^2 s^2 c_{11}] \leq 0\} = (1-\alpha).$$

The roots of this quadratic establish the $(1-\alpha)$ confidence limits for $a_1$.[10] Confidence intervals for the long-run income elasticities were computed from equation (18) by replacing $\theta_1$ by $\theta_2$ and $c_{13}$ by $c_{23}$. Three types of intervals were obtained as solutions of (18a). If the elasticity of adjustment differed significantly from zero $((1-\theta_3)^2 - t_\alpha^2 s^2 c_{33} > 0)$ a closed interval was obtained (e.g., Meat, Poultry, and Eggs, Table 2, below). If the elasticity of adjustment did not differ significantly from zero one of two cases resulted: (a) the interval was composed of all values except a closed interval (e.g., the income elasticity of Dairy Products); (b) the interval was composed of all real numbers (e.g., the price elasticity of Dairy Products).

### *Empirical Results*

The much analyzed United Kingdom consumption and price data are used in the empirical analysis of this section. These data are chosen for illustrative purposes not because the authors feel they are particularly suited to the model but because of their availability and because of the considerable interest displayed in the analysis of these data by Nerlove and Addison.[11] The short length of the series is particularly unfortunate considering that one must rely on large-sample theory in the computation of variances, etc.

Seven commodity groups were selected for study: (1) Meat, Poultry, and Eggs, (2) Dairy Products, (3) Vegetables, (4) Sugar, Chocolate, and Confectionary, (5) Tea, Coffee, and Cocoa, (6) Other Foods, and (7) All Foods. These commodity groups were selected in an attempt to subject the model to a variety of combinations of the square of the multiple correlation coefficients, $R^2$'s, and Durbin-Watson statistics, $d$'s.

The price-quantity indices of the selected commodity groups, as well as the population figures for the United Kingdom, 1920–1938, were obtained

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[10] This approach is due to E. C. Fieller, "The Distribution of the Index in a Normal Bivariate Population," *Biometrika,* 24:428–40. This approach assumes that the two coefficients are distributed normally, a condition that is only asymptotically correct in our case. As an alternative to the above approach, one might compute the approximate variance of the ratio $\theta_1/1-\theta_3$ (see, e.g., Lawrence R. Klein, *A Textbook of Econometrics,* Row, Peterson and Co., Evanston, Ill., 1956, p. 258).

[11] Marc Nerlove and William Addison, *op. cit.,* See also D. S. Ironmonger, "A Note on the Estimation of Long-Run Elasticities," *J. Farm Econ.,* 41:626–32, Aug., 1959, and G. E. Brandow, "A Note on the Nerlove Estimate of Supply Elasticity," *J. Farm Econ.,* 40:719–22, Aug. 1958.

from Stone.[12] The national income figures and the indexes of all prices paid by consumers were taken from Prest.[13] The quantity and income series were placed on a per capita basis, the price and income series deflated by the consumer price index, and all data converted to logarithms. All equations are estimated from the data for the 17 years, 1922–1938.

The least squares estimates of equation (1), under the assumption that $\gamma=1$, are given in Table 1. The least squares estimates of equation (3a),

TABLE 1. STATISTICAL RESULTS OF THE STATIC DEMAND ANALYSIS FOR SELECTED COMMODITIES, UNITED KINGDOM, 1922–1938[1]

| Commodity Group | Price Elasticity | Income Elasticity | $R^2$ | Durbin-Watson Statistic $d$ |
|---|---|---|---|---|
| I. Meat, Poultry and Eggs | −.53 (.21) | .27 (.11) | .715 | .79 |
| II. Dairy Products | −.70 (.22) | .74 (.10) | .888 | 1.39 |
| III. Vegetables | .11 (.05) | .41 (.02) | .435 | 1.11 |
| IV. Sugar, Chocolate, and Confectionery | −.48 (.06) | .23 (.12) | .984 | 1.50 |
| V. Tea, Coffee, and Cocoa | −.52 (.11) | .10 (.05) | .634 | 1.23 |
| VI. Other Foods | −.89 (.31) | .73 (.23) | .905 | .76 |
| VII. All Foods | −.86 (.21) | .25 (.09) | .908 | .59 |

[1] Standard errors are presented in parentheses below the estimated coefficients.

under the assumption that $\beta=0$, are presented as equation 1 of Table 2. Hereafter we shall refer to these estimates as the least-squares estimates. The estimates obtained by the above procedure, under the assumption of unknown $\beta$, are presented as equation 2 of Table 2.[14] Hereafter we shall call these estimates the autoregressive-least-squares estimates.

[12] Richard Stone, *The Measurement of Consumers' Expenditure and Behavior in the United Kingdom, 1920–1938*, Vol. I, Cambridge: Cambridge Univ. Press, 1954. Page and table references for the series used in this paper are as follows: (1) Meat, Poultry, and Eggs: Table 13, p. 53; (2) Dairy Products: Table 30, p. 96; (3) Vegetables: Table 39, p. 121; (4) Sugar, Chocolate, and Confectionery: Table 48, p. 144; (5) Tea, Coffee, and Cocoa: Table 52, p. 151; (6) Other Foods: Table 56, p. 161; and (7) All Foods: Table 66, p. 174.

[13] A. R. Prest, "National Income of the United Kingdom, 1870–1946," *Econ. Jour.*, 58:31–62, 1948.

[14] Much of the calculation was carried out on the IBM 650. The number of iterations required to reach a "stable" solution varied from 2 to 5. A solution was considered to be stable when all $\Delta\theta_i \leq .01$. About 8 minutes of machine time was required for a complete iteration.

TABLE 2. STATISTICAL RESULTS OF THE DEMAND ANALYSIS FOR SELECTED COMMODITIES IN THE UNITED KINGDOM, 1922–1938[1]

| Commodity Group | Equation No. | Elasticity of Adjustment $\gamma$ | Short-Run Elasticity: Price ($a_1\gamma$) | Short-Run Elasticity: Income ($a_2\gamma$) | Long-Run Elasticity: Price ($a_1$) | Long-Run Elasticity: Income ($a_2$) | Autocorrelation Coefficient $\beta$ | $R^2$ | Durbin-Watson Statistic $d$ |
|---|---|---|---|---|---|---|---|---|---|
| I. Meat, Poultry, and Eggs | 1 | .48 | −.27 | .06 | −.56 | .13 | — | .843 | 2.10 |
| | | (.16) | (.18) | (.11) | $[-1.70 \le a_1 \le .45]$ | $[-.90 \le a_2 \le .52]$ | | | |
| | 2 | 1.50 | −.57 | −.11 | −.38 | −.07 | .76 | .913 | — |
| | | (.23) | (.15) | (.17) | $[-.61 \le a_1 \le -.18]$ | $[-.31 \le a_2 \le .21]$ | (.05) | | |
| II. Dairy Products | 1 | .19 | −.28 | .02 | −1.47 | .08 | — | .950 | 2.44 |
| | | (.20) | (.18) | (.20) | $[-\infty \le a_1 \le \infty]$ | $[.87 \ge a_2 \ge 1.30]$* | | | |
| | 2a | .18 | −.32 | −.01 | −1.78 | −.03 | −.22 | .952 | — |
| | | (.17) | (.17) | (.17) | $[-\infty \le a_1 \le \infty]$ | $[.74 \ge a_2 \ge 1.69]$* | (.26) | | |
| | 2b | 1.11 | −.22 | −.09 | −.20 | −.08 | .90 | .947 | — |
| | | (.40) | (.19) | (.23) | $[-.54 \le a_1 \le .24]$ | $[-.76 \le a_2 \le .38]$ | (.06) | | |
| III. Vegetables | 1 | .36 | .09 | .10 | .25 | .20 | — | .661 | 2.48 |
| | | (.22) | (.18) | (.15) | $[-\infty \le a_1 \le \infty]$ | $[-\infty \le a_2 \le \infty]$ | | | |
| | 2 | 1.44 | .06 | −.80 | .04 | −.55 | .91 | .801 | — |
| | | (.21) | (.10) | (.28) | $[-.11 \le a_1 \le .20]$ | $[-1.06 \le a_2 \le -.13]$ | (.05) | | |
| IV. Sugar, Chocolate and Confectionery | 1 | .96 | −.47 | .21 | −.48 | .21 | — | .984 | 1.65 |
| | | (.12) | (.07) | (.14) | $[-.63 \le a_1 \le -.36]$ | $[-.13 \le a_2 \le .49]$ | | | |
| | 2 | .85 | −.40 | .20 | −.48 | .24 | −.41 | .987 | — |
| | | (.15) | (.08) | (.12) | $[-.62 \le a_1 \le -.36]$ | $[-.09 \le a_2 \le .49]$ | (.28) | | |
| V. Tea, Coffee and Cocoa | 1 | .55 | −.30 | .04 | −.54 | .07 | — | .708 | 1.48 |
| | | (.24) | (.16) | (.06) | $[-2.82 \le a_1 \le .32]$ | $[-.12 \le a_2 \le 4.68]$ | | | |
| | 2 | .96 | −.24 | −.14 | −.25 | −.14 | .73 | .778 | — |
| | | (.25) | (.13) | (.16) | $[-.88 \le a_1 \le .04]$ | $[-.53 \le a_2 \le .32]$ | (.18) | | |
| VI. Other Foods | 1 | .13 | −.52 | −.03 | −4.06 | −.24 | — | .984 | 2.28 |
| | | (.11) | (.14) | (.14) | $[-1.31 \ge a_1 \ge 3.57]$* | $[-\infty \le a_2 \le \infty]$ | | | |
| | 2a | .08 | −.48 | −.06 | −6.19 | −.83 | −.25 | .985+ | — |
| | | (.10) | (.14) | (.12) | $[-1.51 \ge a_1 \ge 2.27]$* | $[-\infty \le a_2 \le \infty]$ | (.28) | | |
| | 2b | 1.04 | −.39 | .04 | −.38 | .04 | 1.13 | .985− | — |
| | | (.20) | (.11) | (.15) | $[-.90 \le a_1 \le -.13]$ | $[-.29 \le a_2 \le .42]$ | (.06) | | |
| VII. All Foods | 1 | .37 | −.30 | .04 | −.83 | .11 | — | .971 | 1.74 |
| | | (.12) | (.16) | (.07) | $[-1.80 \le a_1 \le .24]$ | $[-.66 \le a_2 \le .42]$ | | | |
| | 2 | .99 | −.63 | .05 | −.63 | .05 | .77 | .978 | — |
| | | (.25) | (.21) | (.09) | $[-1.83 \le a_1 \le .15]$ | $[-.14 \le a_2 \le .35]$ | (.09) | | |

[1] Standard errors are presented in parentheses below the estimates and approximately 95 percent confidence intervals are presented in brackets below the estimates of the long-run lasticities.
* Note direction of inequalities.

The asymptotic standard errors of the coefficients are presented in parentheses below the coefficients. In the case of the long-run elasticities, approximate 95 per cent confidence intervals are presented in brackets below the point estimates.

In those cases where the initial estimates of the parameters were extremely divergent, two or more different sets of initial trial values were used. For two commodity groups, Dairy Products and Other Foods, two sets of solutions were obtained. That is, the likelihood function possessed two relative maxima. The point associated with the smallest residual sum of squares (largest $R^2$) is "*the* maximum likelihood solution." Both solutions are presented in the table and standard errors are presented below both sets. However, the properties of maximum likelihood apply only to the set of estimates associated with the smallest residual sum of squares. In the case of Other Foods, very little difference exists between the residual sums of squares, i.e., the two solution sets are almost equally likely. In practice one would certainly hesitate before discarding one set of estimates in favor of the other. Such a situation may arise because the model is inappropriate or simply from random errors and the small number of observations used in the estimation. With reference to the former possibility, we note that one estimate of $\beta$ is greater than one, implying that the autocorrelation process is non-stationary. Thus it is possible that the model should include time as a variable. Because of the small number of observations, this possibility was not investigated further.

Of interest is the comparison of the estimates obtained by least squares and autoregressive least squares. Table 3 has been constructed as an aid to this comparison. Although significance points for the $d$-statistic are computed under the assumption of fixed $X$'s[15] this statistic is often computed from the residuals obtained in the least-squares estimation of equation (3a).

Of the seven $d$-statistics computed for the least-squares estimates of equation (3a), one was suggestive of positive autocorrelation, falling in the inconclusive range, but none indicated significantly the presence of autocorrelation. Yet when the autocorrelation coefficient was estimated by autoregressive least squares, four of the estimated autocorrelation coefficients exceeded 0.70. Further, in more than one case the sign of the autocorrelation coefficient differed from that suggested by the $d$-statistic.

Of equal significance are the differences in the estimated coefficients of adjustment. In the majority of instances the values estimated by autoregressive least squares were larger than those estimated by least squares. Two of the more striking comparisons are Meat, Poultry, and Eggs, where

[15] J. Durbin and C. S. Watson state "(Durbin-Watson tests) . . . do not therefore, apply to autoregressive schemes and similar models in which lagged values of the dependent variable occur as independent variables." "Tests for Serial Correlation in Least Squares Regression, II," *Biometrika*, 38:1591, 1951.

TABLE 3. COMPARISON OF PARAMETER ESTIMATES OBTAINED BY TWO PROCEDURES

| Comparison | Number of Cases | |
|---|---|---|
| | Least Squares | Autoregressive-Least Squares |
| I. Equation contains significant autocorrelation in the residuals.* | 0 | 4 |
| II. Short-run price elasticity exceeds twice its standard error in absolute value. | 2 | 4 |
| III. Elasticity of adjustment less than one by at least two standard errors. | 5 | 2** |

* At the five percent level as measured by the $d$-statistic in the least squares equation and as measured by the estimate of $\beta$ in the autoregressive-least-squares equation. The probability level is only approximate.

** The two commodity groups were Dairy Products and Other Foods, the two cases of multiple maxima. In addition the adjustment coefficients for two commodity groups, Meat, Poultry and Eggs, and Vegetables, exceeded one by at least two standard errors.

the estimates were 0.48 and 1.50, and All Foods, where the estimates were 0.37 and 0.99. In no case was the autoregressive-least-squares estimate as much as one standard error smaller than the least-squares estimate, while in three instances the autoregressive-least-squares estimate was more than three standard errors larger than the least-squares estimate. If the two cases of multiple maxima are excluded, no autoregressive-least-squares estimate of $\gamma$ was as much as two standard errors less than one.

The differences in the estimated short-run elasticities are somewhat less striking, but in two cases, Meat, Poultry, and Eggs, and All Foods, the autoregressive-least-squares estimate was more than twice as large as the estimate obtained by least squares.

Differences are also observable in the estimated long-run elasticities and on occasion are of considerable magnitude. However, these differences are less impressive when viewed against the wide confidence intervals of most of these estimates.

Of the confidence intervals computed for the least-squares estimates of the long run price elasticity, 6 contain either minus infinity and/or positive values. The confidence intervals for the autoregressive-least-squares estimates are little better, 5 containing either minus infinity and/or positive values. The confidence interval will be of infinite range if the estimate of $\gamma$ is not significantly different from zero. In such a case at the level of probability chosen the ratio

$$\frac{\hat{\theta}_1}{1 - \hat{\theta}_3} = \frac{\hat{\theta}_1}{\hat{\gamma}}$$

may possess a zero denominator.

In economic terms a $\gamma$ of zero implies that an equilibrium does not exist. Thus in those cases where $\gamma$ is not significantly different from zero the data fail to refute the hypothesis of non-stationarity.

### *Summary and Conclusions*

Two conclusions can immediately be drawn from the results of this investigation. First, if the errors are autocorrelated, estimation of the distributed lag model (3a) by least squares produces biased estimates of the price and income elasticities and of the elasticity of adjustment. Second, the Durbin-Watson statistic computed from the residuals of such a regression is of very low power (often fails to reject the false hypothesis of non-autocorrelated errors). This statistic definitely should not be used as a criterion for concluding that the distributed lag model is superior to the straightforward regression of price and income on quantity, the static analysis. In effect, the coefficient of the lagged endogenous variable picks up part of the autocorrelation in the residuals, at once biasing the estimated coefficients and invalidating the use of the Durbin-Watson statistic.

We offer the following observations on the nature and direction of the bias in the least-squares estimates. While the observations will hold true in many of the situations encountered in economics, the bias need not be in the direction noted.[16] In the presence of positive autocorrelation in the residuals, the estimation of equation (3a) resulted in the underestimation of the elasticity of adjustment. If there was negative autocorrelation in the residuals, the elasticity of adjustment was overestimated. Positive autocorrelation often caused equation (3a) to underestimate the short-run price elasticity and to overestimate the long-run price elasticity. Conversely, if there was negative autocorrelation in the residuals, the short-run price elasticity was overestimated.

Longer series are needed in the estimation of distributed lag models than in the estimation of equations containing no lagged endogenous variables, as only the large-sample properties of the estimates of equations containing the lagged endogenous variable are clearly defined. Further, the stochastic properties of ratios will often result in large variances for the estimated long-run elasticities. Economic and error models and estimation procedures of the type discussed in this paper would seem to be aptly suited to monthly and quarterly data.

The exact nature of the correlation properties of the disturbances is, of course, unknown. However, one could assume a second order autoregressive scheme.

$$u_t = \beta_1 u_{t-1} + \beta_2 u_{t-2} + \epsilon_t \tag{19}$$

and estimate the parameters in a manner similar to that presented in this paper. The model estimated in this paper is certainly to be preferred to the assumption of independent errors. Further, it is possible that one will obtain good estimates of the parameters $a_1$, $a_2$, and $\gamma$ under the assumption of a first order autoregressive scheme although equation (19) or a more

[16] The references cited in footnote 4 give a more detailed discussion of the bias.

complicated relation gives the "true" autocorrelation properties. Such a possibility deserves further study.

We have presented what we believe to be a practical method of estimating equations containing autocorrelated errors. While more effort is required than in least-squares estimation, the operations are fairly well known, being those of matrix multiplication and of least squares itself. It is unfortunate that the likelihood function may on occasion have more than one relative maximum. This results not from the procedure but from the nature of the model assumptions.

The presence of autocorrelated errors in equations to be estimated is a statistical problem and must be treated as such. The use of economic models containing lagged endogenous variables, rather than solving the problem, serves merely to camouflage it.

# TOWARD A PHILOSOPHY OF SCIENCE FOR AGRICULTURAL ECONOMIC RESEARCH*

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FOR some time a considerable gap has existed between applied economics and pure economics. The former, especially farm economics, is usually concerned with immediate practical problems, while the latter is concerned with constructing models whose intent is the theoretical explanation of economic phenomena. The existence of this gap is hardly deniable, but its desirability is perhaps more questionable; the "practical" farm economist may feel that theory is useless and better left ignored.

The latter attitude is hardly tenable, however. In an article which is now something of a classic, Heady forcefully elucidated the need for economic theory in even the most elementary practical research in farm economics.[1] Heady began by formulating the aim of farm economics in a manner to which the most "practical" farm economist could hardly object. The aim is "(1) to guide individual farmers in the best use of their resources and in a manner compatible with the welfare of society and (2) to provide fundamental analyses of the efficiency of farm resources combinations which can serve as a basis for bettering the public administration of resources where agricultural policy or institutions which condition production efficiency are concerned."[2] Furthermore, he formulated the problem of research in farm economics in a thoroughly pragmatic fashion using the concepts and terminology of means and ends. Thus, according to Heady, a model is formulated which indicates a practical optimum in resource efficiency; the present state of affairs is to be determined, and if it falls short of the optimum, the cause of this deviation is to be ascertained; finally, a policy (means) of getting from the "existing" to the "optimum" (end) is to be provided. Theory here is to be used to describe the optimum and also to furnish the guide for investigations concerning the "existing." In the detailed part of his paper, Heady shows that the results of some commonly used procedures in farm economics contravene such well established theoretical laws as that of diminishing returns, and he points out in detail the errors in experimental design which give these results.

Let us take for granted then that farm economists must use economic

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* The investigation reported in this paper is in connection with a Kentucky Agricultural Experiment Station project and is published with the approval of the Director.

[1] E. O. Heady, "Elementary Models in Farm Production Economics Research," *J. Farm Econ.*, 30:201, May 1948.

[2] *Ibid.*, p. 205.

theory, and, as Heady showed, can only ignore it at their peril. What then is the status of economic theory?

At the point where one begins to examine the state of economic theory, one may reach an impasse. However, a philosophical analysis of the issues involved provides an orderly way of reviewing the controversies and confusion surrounding discussions of economic theory.[3] Such an analysis would seem to be a necessary, if not a sufficient condition of progress in this area. Accordingly in this paper we want to present: (1) a logical classification into which *nearly* all the statements of any theory can be grouped fairly readily, (2) a review in the light of the above classification of the viewpoints of several economic theorists concerning the nature of economic theory, (3) what we believe to be necessary criteria of a scientific theory, and (4) two sample investigations, one that meets our criteria and one that does not.[4]

### *A Classification of Statements*

The classification of statements we will give is basically due to the German philosopher Kant. It is based on two distinctions: a priori versus a posteriori and analytic versus synthetic. A statement is a priori if its truth can be known independently of experience. "Independently" here does not mean "in the absence of experience;" rather, the meaning is that the justification or verification of the statement will not require experience.[5] A statement is a posteriori if its truth can be known only on the basis of experience (observation or experiment). A statement is analytic if knowing the meaning of its constituent terms is a sufficient condition of knowing its truth. In other words, to know the truth of such a statement, all that is needed is to understand its meaning. A synthetic statement is simply non-analytic, i.e., to know its truth, in addition to understanding it, one would have to verify it through experience. Some ex-

[3] This is a second paper in response to Karl Brandt's challenge to the American Farm Economics Association of 1955; cf. A. N. Halter, "A Metaphysical Hypothesis," *J. Farm Econ.*, Vol. 40, Dec. 1958. Although the subject of this paper properly falls into the broad category of methodology, it is of a distinctly different character from the analytical methodology that Brandt says has been overemphasized. In 1949 two papers in the same general area as ours appeared in this *Journal*. These were: (a) K. H. Parsons, "The Logical Foundations of Economic Research," Vol. 31, Nov. 1949; (b) B. W. Allin, "Theory: Definition and Purpose," Vol. 31, Aug. 1949. We could not compare our views to those of these writers without unduly extending this paper beyond its intent. We leave this as an interesting exercise for the reader.

[4] Throughout this paper we have tried to express ourselves as clearly and simply as possible to enable the philosophically uninitiated reader to grasp the central ideas. The reader therefore should be warned that the philosophical issues we discuss are more complicated and controversial than may appear. Therefore, we have given a number of references in footnotes which the reader who wishes a deeper knowledge of the subject may pursue.

[5] This meaning of a priori is perhaps not the same as that usually understood in economics. Often "a priori" merely means "theoretical" or "assumed prior to empirical investigation." Heady in the paper cited above perhaps used the term this latter way; cf. p. 209.

amples often used by philosophers may make these distinctions clear.

Ex. 1. "All bachelors are males" is analytic, since the meaning of "bachelor" is "unmarried male" and the statement, "All unmarried males are males," is a logical truth. Since one only needs logic and the definition of "bachelor" to see that "All bachelors are males" is true, this statement is also a priori. One does not have to observe bachelors to verify it; indeed. it would be true even if there were no bachelors.

Ex. 2. Any statement of physical science, such as Galileo's law of falling bodies, will be synthetic and a posteriori. Only experimentation could show that $s = \frac{1}{2}gt^2$ ($s = 16.1t^2$) is the correct law, and not, say, $s = \frac{1}{3}gt^3$.

On the basis of these distinctions, statements can be fitted into three categories: (1) analytic a priori, (2) synthetic a posteriori, and (3) synthetic a priori. (There are no analytic a posteriori statements, since, as noted (implicity) in the discussion of example 1, being analytic logically implies being *a priori*.) The third of these categories is the most debatable from the standpoint of its applicability to the statements of an empirical science.[6]

If one examines the statements of economists in terms of the above classification, one finds that some economists hold that economic theories are composed of analytic statements, others hold they are composed of a priori synthetic statements, while still others hold they are, or should be composed of a posteriori synthetic statements. These different views are held with various degrees of awareness of the philosophical distinctions and terminology we are using. This difference of opinion about economic theory is somewhat startling since most of the statements of the physical and biological sciences can be classed as a posteriori synthetic while those of mathematics are analytic.[7]

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[6] While in theory our categories cover all statements, in practice many statements are not easy to classify (note the remark below in the section on the unique character of economic theory). It should be mentioned here, in addition, that the distinction of analytic and synthetic has been subjected to serious criticism in recent years by Quine, White and other philosophers. Our general feeling in this regard is that the distinction is tenable, but that even if it ultimately is not tenable, it would still be a valuable heuristic device for purposes of clarifying the logical status of statements. The reader who wishes to look into this matter further should see: W. V. Quine, "Two Dogmas of Empiricism," *Philosophical Rev.*, 60:20-43, 1951, or as reprinted in his *From a Logical Point of View* (Cambridge, Mass., Harvard Univ. Press, 1953), and the reply by Grice and Strawson, "In Defense of a Dogma" *Philosophical Rev.*, 65:141-58, 1956.

[7] There is almost a consensus among philosophers of science at the present time that the statements of the natural sciences are all a posteriori synthetic. There is also wide agreement (though there are sharp dissenters) that mathematics is composed of analytic statements. Cf. Herbert Feigl, "Logical Empiricism," reprinted in *Readings in Philosophical Analysis* edited by H. Feigl and W. Sellars (New York: Appleton-Century-Crofts, Inc., 1949), pp. 13-14. Also, Hans Reichenbach, *The Rise of Scientific Philosophy* (Berkeley: Univ. of California Press, 1951), p. 222. Also, R. B. Braithwaite, *Scientific Explanation* (Cambridge: University Press, 1955), Ch. II. Braithwaite uses the terminology "necessary" and "contingent" to mark the distinctions to which we have been referring. Also, B. Russell, *Human Knowledge, Its Scope and Limits* (New York: Simon and Schuster, 1948), pp. 496-97.

*Analytic statements of economic theory*

Let us first consider the view that economic theory is composed of analytic statements. This thesis is thoroughly criticized by T. W. Hutchison. He shows that many basic statements of economic theory such as "Under perfect competition firms are of optimum size" are analytic or, as he calls them, "tautologous."[8] He remarks that at one time or another nearly all parts of traditional economic theory have been called "merely tautologous," "circular," or "question-begging."[9] Some economists, particularly the Austrian school following Menger, have been willing to accept this view of economics; economics is, then, a "pure," "hypothetical," "exact," science on a par with mathematics, and like mathematics consisting entirely of logical deductions.[10] But, as Hutchison points out, this kind of view is not acceptable. Economics is concerned with explaining empirical phenomena, such as the causes of price changes, wage levels, etc. To the extent that the propositions of economic theory are tautologies they cannot perform this function; they are concerned, as Huchison points out, not with wages and prices, but with "wages" and "prices," that is, with the logical relations between concepts and not causal relations between empirical events.

A typical analytic statement will illustrate this point: "If it rains tomorrow, then it will rain tomorrow." Now, such a statement, while it is certainly true, does not tell whether it will rain tomorrow, i.e., it does not provide any empirical information. Precisely because of this lack of empirical content it is certain and necessary; it excludes no event whatsoever and is compatible with all possibilities, i.e., it is true whether it rains or not. Obviously, if I were asked to explain why it rained today, and replied, "It rained, because it rained" (if it rained, it rained), this would be *no* explanation. An explanation of empirical phenomena requires an empirical law which permits confirmation or refutation by testing its implications. Thus, an explanation of why it rained could be given by: "A cold front passed through." This is a genuine explanation because the law "(⅘ of the time) when cold fronts pass through, it rains" is subject to empirical tests.

It is clear then that economic theory if it is to offer genuine explanations of economic events and processes cannot consist entirely of analytic statements. This was Hutchison's main point. However, that he was not completely understood is shown by the following comment in Koopman's recent book: . . . Professor Chamberlin's objection that this reduces the 'explanation' of increasing returns to a tautology misses the point. As

[8] T. W. Hutchison, *The Significance and Basic Postulates of Economic Theory* (London: Macmillan and Co., 1938), p. 28.

[9] *Ibid.*, pp. 55-57.

[10] *Ibid.*, pp. 58-60.

Hutchison has emphasized all pure theory, that is, all study of the implications of given postulates is tautological in character. . . ."[11] But if we are correct, Hutchison's point was precisely that such a "pure theory" is no explanation; consequently, Koopmans' emphasis, at least, is misleading.

We must guard against misunderstanding (as indeed Hutchison did) by making this qualification. Theories may contain many tautologies in virtue of their concept structure as long as they contain empirical propositions too, so that the theory as a whole permits empirical predictions to be made.[12] Thus, "Tom is a bachelor" might be taken as an explanation of why "Tom is really a boy at heart." The "theory" assumed here would be the analytic statement or definition, "All bachelors are males," and the *synthetic a posteriori* proposition, "All males are really boys at heart."

*A priori synthetic statements in economic theory*

Many writers have felt that economic theory as a whole has an a priori character, but have still maintained that it has empirical significance. In effect, they maintain that (at least some) theoretical statements are a priori synthetic; however, their expressed views usually are not quite this precise.

Typical of this sort of approach are the opinions Professor Knight expressed in a vigorous critique of Hutchison's book. His discussion makes clear that he would accept the idea that some statements, in particular mathematical statements, can be a priori and synthetic. In discussing the status of mathematical propositions he uses such terms as "a priori validity," "universally necessary," "a priori necessity."[13] The synthetic element comes in when he contends that mathematics gives us truths, abstract to be sure, "about the real objective world."

He argues that the basic postulates of economics are known by "intuition," and they do not require any empirical verification. In particular he lists three propositions which he says are basic to economics (the first of these states some human behavior involves allocating means limited in supply among alternative modes of use in realizing ends), and which are

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[11] Tjalling C. Koopmans, *Three Essays on the State of Economic Science* (New York: McGraw-Hill Book Co., Inc., 1957), p. 152.

[12] This point is clearly illustrated by the simplified model of national income determination used by A. G. Papandreou, "Explanation and Prediction in Economics," *Science*, Vol. 129, No. 3356, April 24, 1959, p. 1096. Of the five equations used, two are given as definitions, e.g., his first equation $Y = C + I + G$ defines national income, where $Y$ stands for the dollar value of national income, $C$ for consumption (household expenditures), $I$ for investment, and $G$ for government expenditures. Three equations involve a posteriori assertions; thus, Papandreou's third equation, $C = a + bZ$ ($Z$ is disposable income), embodies a hypothesis concerning the consumption behavior of households.

[13] Frank H. Knight, "What is Truth in Economics?" *J. Political Econ.*, Vol. 48:9, Feb. 1940.

known by every "rational" and "competent" mind. (This latter clause suggests that their denial is not just false, but absurd. Being absurd is usually taken as a sign of the analytic, and not just of the a priori.) Finally, he claims that we know these basic postulates "fully as certainly as we know the truth of any axiom of mathematics or of logic."[14]

Essentially, then, Knight maintains that basic economic theory is certain and a priori and at the same time it is synthetic in that economics describes a "realm of reality." However, our economic knowledge is "intuitive" since it depends to a large extent on our "inside" knowledge of human behavior; that is, it deals with our intentions, expectations, etc., which are not accessible to external observation. This kind of knowledge is *necessary* because its acquisition is a necessary constituent of our becoming part of the human community and communicating with others.

However, some things said by Knight are puzzling and do not fit the above interpretation of his views. For instance, he says we do not know the three basic postulates either a priori or by "one-sided deduction from data of sense observation."[15] It is difficult to see how we can know these propositions with as much certainty as mathematics, which he grants is a priori knowledge, unless they are a priori too.[16] Actually, as Kant points out, certainty is a criterion of a priori knowledge. Perhaps Knight used a priori here in the sense of a priori analytic, since his "either or" probably refers to the positivistic dualism of analytic versus empirical of which he accuses Hutchison. In that case what he says would be consistent with the above interpretation of his over-all views.

A similar position to Knight's is taken by Robbins in his well known book though his remarks, as Koopmans' notes, have a certain "statesmanlike vagueness."[17] According to Robbins, the postulates of economics involve "simple and indisputable facts of experience relating to the way in which the scarcity of goods which is the subject matter of our science, actually shows itself in reality."[18] (Compare this to Knight's first postulate.) Such postulates are not subject to "extensive dispute." "We do not need controlled experiments to establish their validity: they are so much the stuff of our everyday experience that they have only to be stated to be recognized as obvious."[19]

But, as Koopmans shows in his discussion, Robbins' postulates turn out

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[14] *Ibid.*, p. 16.

[15] *Ibid.*, p. 17.

[16] In passing we might note that it would be even more difficult to interpret the remarkable doctrine he puts forward that one can verify "empirically" the theorems of arithmetic and algebra by counting beans. Most philosophers would now agree that such counting logically presupposes the theorems in question.

[17] Koopmans, *op. cit.*, p. 136.

[18] Lionel Robbins, *An Essay on the Nature and Significance of Economic Science*, 2nd ed. rev. and ext. (London: Macmillan, 1940), p. 78.

[19] *Ibid.*, p. 79.

to be far from "obvious" on closer inspection.[20] Entirely aside from this, it must be noted that appeals to "intuition," "obviousness," "self-evidence," etc., have long since been discredited in mathematics and the natural sciences. This has led most modern philosophers of science to espouse empiricism and to maintain that all knowledge of fact must be based on observation. Scientists' disillusionment with appeals to "self-evident" principles (supposedly known a priori) which later were seen to be false, or at least not well founded, have fostered this approach. Since modern philosophical analysis has made it clear that "intuitionistic" doctrines of necessary knowledge of reality essentially involve the doctrine of valid a priori synthetic statements, most philosophers of science now rejects the view that there can be a priori synthetic knowledge, at least in science.

We feel, therefore, that the weight of opinion requires proponents of a priori synthetic statements in economic theory to assume the onus of proof for their position. But we do not wish to deny flatly that economic theory may have a *sui generis* character as compared to the mathematical and natural sciences, i.e., being neither tautologous nor straightforwardly empirical.

*Unique character of economic theory*

This *sui generis* viewpoint has been put forward by Fraser and recently by Papandreou. Their views are rather subtle from a logical standpoint and to some extent slip between the philosophical categories we have been using. Whether this is an argument against their views is itself probably a debatable philosophical question. However this may be, according to Fraser the statements of economic theory are not a priori tautologies (what he calls purely hypothetical laws), nor are they simple empirical or historical generalizations (which he calls enumerative laws); rather, they are a combination of these. His point of view is most directly expressed in the following quotation.

"[The] union of the enumerative and the universal is well illustrated in the Malthusian Law. Neither of the two formulations of the law given above represents what Malthus wanted to say.[21] He was concerned to assert a combination of them: namely that population would constantly press against subsistence because the fecundity of the human race was greater either then its foresight or the fertility of land. In its purely historical aspect this proposition is false: in its purely hypothetical aspect it

[20] Koopmans, *op. cit.*, p. 137. (Incidentally, in his rejoinder to Hutchison's reply, Knight admits that in giving his ultimate economic principles he is only "giving my opinion." cf. *J. Political Econ.*, 49:753, 1949.)

[21] These are:

a. Population will increase up to the starvation level. (Enumerative Law)

b. If people beget the maximum number of children of which they are biologically capable, population must increase up to the starvation level. (Hypothetical Law)

is a truism. But the whole point of it lies in the fact that it is neither purely historical nor purely hypothetical. It is an attempt to interpret a concrete economic situation with the help of certain a priori principles. And it can only be properly appraised if this is clearly understood."[22] Fraser adds, and we think this is the case, that this view of economic statements would explain why so many economic laws have been stated as "tendencies."

It happens that a "because" statement, as such, cannot be a direct statement of fact. However, this does not rule out that its verification may still be just a matter of observation and inference from observation. In physics, to use a simplified example, we can say that the pressure of the gas increased *because* we decreased its volume. This "because" explanatory statement is accepted since it can be deduced from Boyle's Law that an increase in pressure is correlated with a decrease in volume. The law in turn is accepted because specific deductions (predictions) have been empirically found to be the case. Thus, even if most economic theories are explanatory in Fraser's sense, this might be more a matter of the way the theories are verbally expressed than of their actual epistemological status.

However, some doubt is cast on this easy solution by a recent investigation of the nature of economic theory by Papandreou. He has worked out in great detail and with considerable logical finesse and precision a meta-theory about economic theories.[23] Very briefly, according to him, economists formulate models rather than theories, the difference being that the "scope" of a model is undetermined because the *social space* in which the theory is meant to hold is not specified.[24] (The American economy in the 1950's, a feudal economy, etc., would be social spaces or parts of social spaces.)[25] Hence, he says a model can be *confirmed* but not *refuted*. Furthermore, models serve as explanatory devices but not as predictive devices, since a predictive theory would require the scope of the model to be determined. The parallels here to Fraser should be obvious.

We are not disposed to argue that this *sui generis* view may not be an appropriate description of most existing economic theory. The real question is whether this is a satisfactory state of affairs. In the natural sciences all theories are characteristically subject to refutation if their implications are not confirmed by observation. Indeed, Popper has proposed, and we would accept this, that the criterion of the scientific status of a statement

[22] L. M. Fraser, *Economic Thought and Language* (London: A & C Black Ltd., 1937), p. 52.

[23] Papandreou's recent book, *Economics as a Science* (Chicago: Lippincott, 1958), presents his views in detail. The *Science* article cited above is an excellent semi-technical summary of his theory.

[24] *Papandreou,* op. cit., p. 1098.

[25] If one defines the social space in terms of the theory, circularity results. Similarly, if we define a perfect market as one in which the law of supply and demand holds, the "law" that price is determined by supply and demand in a perfect market is only a tautology.

is precisely its falsifiability.[26] It follows immediately that the statements in Papandreou's nonrefutable models are not "scientific." However, the question economists must face is not that of the definition of "science," but it is this: should economists try to move in the direction of making their theories scientific in Popper's sense?[27]

*Empiricist point of view*

A number of writers have given, as would the authors of this paper, an affirmative answer to the question raised at the end of the previous section. This answer fits in with the empiricist view. According to this view, economic theories should contain hypotheses of a direct empirical nature (that is, they should be synthetic a posteriori statements) as well as definitions or conceptual tautologies, so that these theories as a whole would have factual implications which would permit observational tests to be made.

Among the writers subscribing to this empiricist point of view are Hutchison, Friedman, and (with some reservations) Koopmans.[28] Hutchison makes it clear, especially in his reply to Knight,[29] that he believes economics must seek to become more of an empirical science, and that progress in this direction will consist in the construction of empirically testable theories. His point of view is clearly indicated by his favorable quotation of a remark of Professor Susan Stebbing, "A scientific theory that is incapable of experimental test is valueless."

Likewise, Friedman makes it clear that he takes an empiricist view: "Economics as a positive science is a body of tentatively accepted generalizations about economic phenomena that can be used *to predict* the consequences of changes in circumstances."[30] He makes a point of attacking those who think economic theory is to be "tested" by the conformity of its assumptions to reality, where this conformity is to be estimated intuitively

[26] This statement, which is controversial, is given extensive defense in K. R. Popper's, *The Logic of Scientific Discovery* (London: Hutchison, 1957). For a readable survey of the issues cf. C. Hempel, "Problems and Changes in the Empiricist Criterion of Meaning," in L. Linsky (ed.), *Semantics and the Philosophy of Language* (Urbana: University of Illinois Press, 1952), pp. 163-88. Popper has given an excellent summary of his position in his "Philosophy of Science, A Personal Report," in C. A. Mace (ed.), *British Philosophy in the Mid-Century* (London: Allen and Unwin, 1957) pp. 155-94.

[27] Papandreou has indicated substantial difficulties in achieving this end if his meta-theory is a correct account of economic theory.

[28] Heady, *loc. cit.*, p. 202, seems to slide from the first view given above to the last one. Thus he speaks of the necessary conditions (of profit maximizations) as being as exact in the sense of mathematical proof, and having equal or greater possibility of empirical verification than the laws of supply and demand. Surely it is just confusion to think that something which can be mathematically proved requires empirical verification.

[29] T. W. Hutchison, "The Significance and Basic Postulates of Economics: A Reply to Professor Knight," *J. Political Econ.*, 49:736, Oct. 1941.

[30] Milton Friedman, Essays in Positive Economics (Chicago: Univ. of Chicago Press, 1953), p. 39 (our italics).

or on an unsystematic common sense basis. Finally, Koopmans[31] also subscribed, though with some reservation, to this same sort of view in his recent well known essay. He explicitly indicated he is in general agreement with Hutchison that the time has come when economic theories should be subjected to a more rigorous direct or indirect testing by systematic observation.

### *Criteria of a Scientific Theory*

Let us now sum up by presenting some criteria of scientific theories which would be in accordance with the empiricist viewpoint. These criteria are, we believe, basic and necessary, rather than sufficient and complete. First, the statements of a theory must be in part (usually, in the main) synthetic a posteriori statements. This, of course, does not preclude inclusion of analytic a priori statements, i.e., what are usually called definitions. Second, an adequate scientific theory must be genuinely descriptive and explanatory. These properties will be present if the theory can explain given data by deductions from synthetic a posteriori laws, and also permits the deduction of predictions which can be compared with observations. Such a theory, thus will be empirically testable. Third, a genuine scientific theory must be formulated in such a way that it will stand or fall on the basis of empirical tests. A single well established contrary instance refutes a theory consisting of universal laws; however, if a predicted event is actually observed the theory is confirmed until further tests are provided.[32] Of course, in practice, there always is some question about how "well established" any instance is. It must be admitted that if the theory contains statistical laws, a conclusive refutation is not possible. However, the techniques of statistics and sampling provide reliable means for testing and rejecting statistical laws.[33]

### *Two Illustrative Examples*

Although an immense quantity of research has been carried out in quantitative economics and, in particular, agricultural economics, it is difficult to find single pieces of work that satisfy the criteria of the previous section. One positive example to which we can point and will briefly discuss here is Herman Wold's work in demand analysis.[34] Another example is the work of Carl Christ in input-output analysis.[35] The other kind of example that does not satisfy our criteria is more readily available

[31] Koopmans, *op. cit.*, p. 132.

[32] Note in this connection Papandreou's statement that economic models can only be confirmed and not refuted.

[33] For a thorough discussion of the complications involved in testing statistical hypotheses see R. B. Braithwaite, *op. cit.*

[34] Herman Wold, *Demand Analysis, A Study of Econometrics* (New York: John Wiley & Sons, 1953).

[35] Cf. *Input-Output Analysis: An Appraisal*, Nat. Bu. Econ. Res. (Princeton: Princeton Univ. Press, 1955).

in agricultural economics literature.[36] The example we will discuss is Heady's "An Econometric Investigation of the Technology of Agricultural Production Functions." This will be examined critically since it contravenes the empiricist view we have espoused.

### *Wold's demand analysis*

Wold calls his work "applied demand analysis" and claims it will answer questions of economic policy. However, from the standpoint of illustrating how it fulfills the criteria of scientific work we would prefer to say his analysis is a test of a piece of classical economic theory.

First, he hypothesized that the demand functions with respect to price and income are of a particular mathematical form. He further hypothesized the form of the function of supply on price and the mechanism of price movement. Then from one source of data, family budgets, he estimated, using the conventional regression approach, the income elasticities (parameters of demand equations in respect to income). From a second source of data, market statistics, he estimated price elasticity. Fortunately from the standpoint of theory testing, in Wold's native country, Sweden, for which the demand elasticity estimates had been made, an event occurred that would be the "ultimate" for any scientist. In 1949 the government removed food rationing and fixed the price of various food stuffs. This provided the opportunity for experiment that the social scientist bemoans he never has and which is often made the basis of arguments that social theories cannot take the status of theories in natural science. Juréen, an associate of Wold, seized the opportunity to make a forecast. Based upon the estimated demand elasticities, the assumption that real income had increased by 30 percent since the description period of 1930-1939, and the 1949-1950 fixed price, the predicted consumption of 1949-1950 was deduced. This predicted value was compared with the observed 1949-1950 consumption with the result that Wold concluded, "On the whole it may be said that the forecast was successful."[37]

We conclude that *in principle* Wold has provided one test for a piece of economic theory which is in accordance with our criteria.[38] Wold's work

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[36] Of course, we are not implying that *no* examples meeting our criteria are to be found in agricultural economics literature.

[37] *Ibid.*, p. 25.

[38] Serious questions arise concerning the meaning of "successful" in such a context. For example, the predicted consumption of butter was 11.5 kg. per capita, while 13.7 kg. per capita were actually consumed. In terms simply of the figures being used this is an error of 19 percent. Is this amount of error acceptable, or is it too large? Friedman (*op. cit.*, pp. 16-23) discusses this difficult question with great acuteness. He points out that in physics not only must you know what the margin of error is, you must have some convincing criteria to determine when a theory ceases to "work" because the error is too large. He suggests two standards to help determine this question in economics. First, of two otherwise equally acceptable theories, the one with the smaller margin of error is preferable. Second, one should strive to reduce the margin of error as much as possible, unless the cost is prohibitive.

alone does not establish this theory scientifically; obviously further tests are needed. One possibility might be to use Wold's procedures for analyzing data and making predictions in other countries. Or, one might join Wold's theory to other hypotheses and try to make predictions of entirely different economic events such as exports and imports. By this sort of piece-meal procedure a body of theory with descriptive and explanatory power is built.

*Heady's production functions*

The introduction to this paper referred to Heady's insistence that the research results of agricultural economics be "practical." We have discussed the empiricist test of a scientific theory. We have stressed that it is the application of a theory in prediction that provides its test of scientific truth. Such theories we believe will be the most useful. However, despite his practical bias, in 1957 we find Heady still trying to fill "empty shoeboxes."[39] He says concerning the status of production economic theory, ". . . this large skeleton of theory exists, little empirical flesh has been fitted to it."[40] Not only has little empirical flesh been fitted to the bones, but the joints have never been moved and no attempt has been made to ascertain whether the monster will topple if any one would attempt to give it a shove into the empirical brambles of observable events.

Heady refers to a number of experiments carried out on crops and livestock that provided estimates of parameters in several mathematical equations descriptive of the production functions in question. He says statistical criteria were used in selecting production functions for "predictions" as a basis for "economic decisions." This part of the procedure is the equivalent to Wold's estimation of the elasticities of demand. But Heady provides no predictions that can be subjected to test in Wold's sense. (i.e., given certain initial conditions aggregative events can be predicted and tested against actual observations.)

However, if Heady means he can predict the combinations of inputs Iowa farmers are using in hog production, then he has provided us with some testable hypotheses. This kind of test on a smaller scale than Wold's is perfectly satisfactory for confirming or refuting production theory. For example, one could use Heady's estimates for the parameters in the pro-

[39] E. O. Heady, "An Econometric Investigation of the Technology of Agricultural Production Functions," *Econometrica*, 25:249, April 1957.

[40] Incidentally, a contrary conception of the status of economic theory is expressed in the following quotation from E. O. Heady, *Economics of Agricultural Production and Resource Use* (New York: Prentice-Hall, Inc., 1952), p. 16: "Economic principle provides a common logic whereby scientific objectivity and interpersonal validity of conclusions can be guaranteed even in the absence of empirical analysis. The laws or theorems of economics are a deductive set of propositions derived by the rules of logic from basic propositions called postulates." This would imply that economic theory is a priori analytic and is exactly the view attacked by Hutchison. As we said above, if theory has this status then there are no "empty shoeboxes" to fill.

duction functions for a group of corn and hog farms as a posteriori statements. Then using the propositions or hypotheses given by a study of the decision making processes of farm managers and the definition of a maximum, one could deduce a prediction of the maximum profit point for a group of farms. This prediction could then be tested by actual observation of this group of farms. In effect this would provide a test for the parameters of the production function and for the adequacy of the description of the decision making process. Until such a definitive test on reality is provided we fail to see how statistical analysis of one set of experiments will accomplish even the first of Heady's aims, i.e., to guide individual farmers in the best use of their resources. How can the farmer be convinced the statistician's parameters are his? Hence, until such a test is provided in which predictions and observations are compared, we can only conclude that such production function estimates are tentative and that so-called "production theory" is close to mere speculation.[41]

## *Conclusion*

We have presented the view that the key propositions of economic theory should be a posteriori synthetic. We have given references to recent writers in general economics who also take this empiricist position. If this empiricist view is accepted, then what are the implications for agricultural economics? While we cannot attempt a full exposition here, two possible implications can be given in concluding this paper. (1) If economic theory describes and explains the working of the whole economic system, agricultural economics should try to use certain of these more general empirical propositions in conjunction with empirical statements that have reference to agriculture in particular, and thereby deduce predictions concerning possible changes in the agricultural sector. (2) If economic theory provides a general explanation of the behavior of firms and households, agricultural economics should provide a testing ground for these propositions. By using the general laws of economic theory and the specific "initial conditions" which might be found true for agricultural firms and households, the farm economist could provide an empirical explanation of farmers' behavior. Then, and only then, can we see that the farm economist can take the role of teacher, engineer, or moralist. We are a long way from providing guides to farmers that reach beyond their own "good" common sense.

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[41] Needless to say we are not singling out Heady for personal condemnation but we refer to him because his work provides an illustrative example which will be well known to all our readers. Similar strictures could be urged against the work of one of the authors of this paper; cf. A. N. Halter and C. Beringer, "Cardinal Utility Functions and Managerial Behavior," *J. Farm Econ.*, Vol. 42, Feb. 1960. However, considerable caution was used there in noting that statistical significance of relations was not a test of the decision making theory of which utility measurement is a part.

# NOTES

## STATE OF THE ARTS IN AGRICULTURAL MARKETING RESEARCH

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RECENTLY, it was necessary for me to attempt a review of the marketing literature which has been coming from our agricultural experiment stations and the U.S. Department of Agriculture since 1954. The general purpose of this review was to help determine what additional knowledge has been gained during recent years about the marketing of farm products both in general and for specific commodities. (Marketing, in this instance, was broadly interpreted as that series of events which takes place in moving products from initial producer to final consumer along with the various firms and institutions which both organize and make the decisions necessary to accomplish these activities.) After completing this review, I was left with some definite impressions and conclusions concerning our progress in marketing research.

No claim is made as to the completeness or adequacy of the sample of the literature reviewed. Let it suffice to say that real effort was made to be as complete as library, bibliography and personal contact resources made possible. Over 360 bulletins and articles written by workers both in the USDA and the large majority of the state colleges were reviewed.

It should be made clear that no generalization is going to be made concerning the value and usefulness of this research in answering a particular problem in a particular area for a particular group. Rather the comments are from the viewpoint of another researcher who was trying to interpret facts, generalizations and insights which might be valuable and useful in a broad or total marketing context. It also is quite true that the comments and generalizations have been reached using my own standards of values and judgment. In spite of these shortcomings, however, it is hoped that these impressions and conclusions may prove stimulating and provocative to other workers in the marketing field.

The title, "The State of the Arts" was deliberately chosen. It does not imply that marketing research cannot be scientific. However, the following comments do not deal with the excellence (or lack of it) exhibited in the researcher's methodology or theory. Rather they focus on the type of published product which is produced and the types of problems which we collectively have selected for analysis. The perception and evaluation of important problems and the publishing of the results are certainly more an art than a science.

*The Research Report*

One general impression was that the published reports of our marketing research have many shortcomings. The procedure and data sources used are only briefly noted. Tabular detail on the data is omitted or incompletely included. Pictures and graphs (sometimes in color!) are there. But the next researcher who wants to use the material either as a basis upon which to build further work or to add to other findings in his search for broader generalizations, finds the necessary detail lacking. In many instances, unless the researcher is specifically interested in the particular problem being reported, the research report is useless to him.

In this particular area, the USDA does a better job than most experiment stations. Researchers in the USDA often report data and methodology in detail. Writing for "popular consumption" has often been separated from the basic research report itself.

Many experiment stations are apparently under heavy pressure to make research results "readable and attractive" to the general public. Certainly this goal in and of itself cannot be criticized. But when this goal overrides all other considerations, then one of the outputs of research efforts—to furnish knowledge upon which other researchers build further—has been wastefully neglected.

In the past, experiment stations met the problem of the dual market for research results by publishing a popular bulletin series and a technical bulletin series. Apparently in a great many states this practice has given way to the single report which tries to serve both types of potential users, and thereby, in my opinion, often truly satisfies neither. In some areas of research work where the professional journals serve a research reporting role, this popular report may be adequate. However, this *Journal*, which would be one of the outlets for reporting agricultural marketing research, has not been widely used in this manner.

*The Problems Being Researched*

Many working in the field of marketing would hold that the meaningful and truly critical marketing problems are those which cut across commodity lines and take on general functional, institutional or behavioral aspects A conclusion which must be made after a study of our recent literature, however, is that formulation of research problems in this broad manner is not widespread. Commodity specialization is the basic organizational framework of agricultural economics departments in the colleges (and much of the USDA) and research problems are conceived and reported largely in a commodity framework. If broader, across-commodity-lines research is of greater usefulness, then again the USDA deserves special mention. Of this type of research (though not propor-

tionately great in amount) USDA workers tackle and publish a sizeable share.

Since the bulk of the agricultural marketing research is orientated around commodity lines, a brief summary of the research published by commodity areas should give some insight into similarities, or differences, of marketing problems as seen by the specialists in different commodity fields. It is to some of these we now turn.

As one surveys the research output in the *livestock and meat* area, there are two major impressions. The most important marketing problems apparently center around the market channel used between the farm and first buyer and the inadequacies of the livestock grading system. The great bulk of recent literature bears on these two areas. State after state has published detail of the proportion of each kind of livestock which is sold by farmers to each type of buyer. Research studies have probed grading problems from all angles—accuracy, method, consumer recognition and preference, etc. Operating costs and procedures of local buying agencies, such as auctions, have also received considerable attention. However, aside from a few studies on retail meat merchandising and consumer preferences, the marketing activities taking place after the first buyers have received little attention from the researcher. The attention of livestock marketing researchers is largely drawn close to the farm levels.

Research in *grain* marketing, is outstanding because of its relative scarcity. Grain grading, farm storage and elevator operation have received some attention. However, the vast complex of handling, milling, baking, distribution, etc. which takes place from the elevator onward has received little research attention.

Research in *dairy* marketing is in direct contrast to grain. The available literature is quite voluminous. The problems which have received research attention range widely throughout the system. Country assembly, bulk handling, plant costs and operations, consumer product distribution and merchandising practices have all received attention. Presumably because of the prevalence of marketing orders, pricing problems, trade practices, impacts of legislation, promotion and other similar issues have also been subjects for investigation.

Similar to dairy, *poultry* research has been far-ranging and varied. Market organization, integration, pricing practices, market news, retail practices, costs and practices of handlers and processors all have been subjects of research reports. Quality and grading, consumer preference and market expansion have also been covered.

*Fruit and vegetable* research is similar to livestock in that it has focused its major attention on a limited area. Quality deterioration, "better-methods" studies of loading, handling, and packing have received the

greatest attention. Some work has been reported in the frozen food and canning industries and wholesale market reorganization. In this commodity area, however, problems which have been the subjects of research effort seem to be concentrated on activities occurring early in the market channel.

Of course, there are some areas of substantial research effort which fall outside of the commodity boundaries. Transportation and retailing have received considerable research attention apart from a strictly commodity approach. In both of these areas, the work has had a strong engineering, "improved-method" bias. Such subjects as how to load watermelons, crate cauliflower, restock grocery shelves and handle the grocery checkout illustrate the direction much work has taken. The cost-and-margin research should be mentioned also, if for no other reason than its substantial volume. Most of this work apparently is now being done by the USDA. The principal reaction one received from reviewing this research is one of great confusion. There are literally hundreds of "pieces" which are getting smaller and more specific. Detail is now available on the marketing cost for a product shipped from area A to city B and "sold either through independents or chains." However, lack of any uniformity of procedure and definition of institutions or functions make it extremely difficult to put these pieces together or to use them in any analytical way. In spite of the flowing detail, it is very difficult to get any perspective on the important questions as to what is going on in the area of marketing costs and why.

### *Some Concluding Observations*

If the research reviewed is roughly an indication as to the general direction research in agricultural marketing has taken, some interesting questions are raised. Either the types of critical problems do vary widely from commodity to commodity, or the art of problem conception differs widely among research specialists of the various commodities. Either marketing problems which are focused near the farm level *are* more critical and demanding or we as researchers have not yet grown up to the idea of marketing being the entire process from farmers to consumers. (An interesting sidelight here is gained from a study of the actions of the multitudinous research advisory committees which the USDA has set up to help guide its program. The 1960 research recommendations of six different commodity committees were analyzed. Research proposals to study quality or grading problems almost invariably received a high priority rating. Proposals to attack pricing, processing, retailing or market organizational problems usually received a rating of medium or low priority.)

What about the art of conceptualizing and evaluating marketing prob-

lems? Why were dairy and poultry researchers either willing or able to turn their research efforts loose on such a broad and oftentimes highly imaginative front? Both of these industries have been in substantial market price trouble. Did this mean the researcher received more pressure—and more freedom—to probe for answers to the trouble? Both of these have been industries of substantial and rapid technological and innovational change. Does such a change result in making the researchers more exploratory and innovational in their concept of problems which might be studied? In both grain and livestock, the processing industries consist of relatively few and large firms. Does this indicate that college and government researchers cannot find research entry into areas dominated by larger firms? These are just a few of the interesting hypotheses which might explain our uneven research development.

Finally after a review task such as this, there is a sense of some frustration. Certainly, much of the work is well done and serves a useful purpose. But how much further have we come in the development of useful theory and generalizations which will aid in anticipating and solving future problems? In the period 1955-59, some 50 major contributed articles (about 25 percent of the total) that appeared in this *Journal* could be considered to be marketing oriented. However, half of these were articles dealing with a particular commodity preference, quality or firm operational problem. It usually takes the direct assignment of the annual meetings to force our marketing scholars into analyzing the broader issues and problems. In an earlier critique of marketing research it was noted that little progress had been made in the development of useful generalizations and concepts.[1] Now some years later this apparently is still true to a large extent. But of greater concern, judging from the type of problems we select to use our resources on, not too much progress in this area can be expected in the near future.

However, the still more disturbing conclusion is that unless sharp improvements are made in the reporting of research, scholarly work in the literature will not be too fruitful even if some of our workers take the time to do it. The criticism has been levelled at marketing researchers that they are wasteful in the sense that they attack each new area as one in which "little previous work has been done."[2] One of the reasons then given for this situation was that we had a terminology problem which made addition difficult. After a review of our recent published literature, inadequate reporting of pertinent research detail must be added as a major deterent to the future usefulness of our work.

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[1] R. L. Kohls, "A Critical Evaluation of Agricultural Marketing Research," *J. Farm Econ.*, 39:1604, Dec. 1957.

[2] *Ibid.*, p. 1602

# A COMPARISON OF THE PARITY RATIO WITH AGRICULTURAL NET INCOME MEASURES—1910-1958

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THIS article examines the effectiveness of the parity price ratio as an indicator of per capita, per farm, and per worker net farm income, money and real.

The parity price ratio (or simply the parity ratio) is the ratio of the index of prices received by farmers to the index of prices paid by farmers for commodities, interest, taxes, and wages. The forerunner of the prices received component of the parity ratio was first published in 1909, and has since been updated and expanded into the present index of prices received. The forerunner of the prices paid component was first published in 1928, and received statutory status with the establishment of the Agricultural Act of 1933.[1] When the index of prices received and the index of prices paid became available, it was a natural development to divide one index into the other, thereby obtaining a measure which gives an overall indication of the purchasing power of farm commodities.

The importance which many organizations and individuals attach to parity prices is indicated by the extent to which the parity price concept runs throughout farm legislation. resolutions of political parties, resolutions of farmers' organizations, journal articles, editorials, etc. This importance stems from the feeling of many that parity prices of particular commodities give a measure of how well farmers producing these commodities are faring relative to how they fared in some base period, and that these commodity prices are "fair" prices. Unlike parity prices for specific commodities, the parity ratio does not have a direct legislative effect and is rarely designated by name in resolutions of organizations. However, it is designed to give an indication of the overall purchasing power of farm commodities relative to their purchasing power in a base period, a concept which does run throughout farm legislation and resolutions of political parties and farm organizations.

Since prices received by farmers and prices paid by farmers, which determine the parity ratio, also affect the well-being of farmers, the parity ratio is regarded by many as a good indicator of the well-being of farmers in general. More specifically, the level of the parity ratio is thought to

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[1] *Major Statistical Series of the U. S. Department of Agriculture,* Agri. Hb. No. 118, Vol. I, Aug. 1947, pp. 2, 34.

give a good indication of one of the following methods of estimating the well-being of farmers:

(1) Net *money* income per capita, per farm, or per worker.

(2) Net *real* income per capita, per farm, or per worker.

(3) Income of farmers compared to income of non-farmers on a per capita or per worker basis (the parity income concept).

This article examines the effectiveness of the parity ratio as an indicator of the level of (1) and (2) above. It does not examine the relationship between the parity ratio and the parity income concept. In order to give insight into relationships between the parity ratio and the measures in (1) and (2), this article also compares the parity ratio with the aggregate income measures from which the per capita, per farm, and per worker income measures are derived. Finally, the relationship between the parity ratio and per capita income of farmers from all sources, including income which they derive from non-farm sources, is examined.

### *Methodological Approach and Data Used*

In order to evaluate how closely the parity ratio reflects the level of net money income from farming, the parity ratio was correlated separately with the per capita net agricultural income of the farm population, the net income of farm operators from farming per farm, and the net income of farm workers from farming per worker. In order to evaluate how closely the parity ratio reflects the level of net real income from farming, the parity ratio was correlated separately with the same measures deflated by the index of prices paid by farmers for family-living items (1947-49 = 100).[2] The parity ratio was also correlated with each of the aggregate income measures from which the above income measures are derived, and with per capita and aggregate net income, real and money, of the farm population from all sources. These correlations were made for the period 1910-58 and specific periods within these years.[3,4]

Since visual examination of charts (with the parity ratio plotted against each net income measure) indicated that different relationships existed between the parity ratio and the net income measures for the periods 1910-

[2] This index was chosen over a more general index of prices paid by farmers for all farm expenses because many farm production expenses have already been deducted in calculating net income.

[3] Simple correlation was used since the object was to see how good an indicator the parity ratio by itself is of the variables it is compared with.

[4] All of the net income data (except the per capita net income data) and the index of prices paid by farmers for family living items (1947-49 = 100) were taken directly from or computed from data in *The Farm Income Situation*, No. 174, July 1959, Agri. Marketing Serv., USDA. Due to changes in estimates of the farm population, the per capita net income data were taken from *FIS* 177, Feb. 1960.

All of the net income figures used in this article included income credits for government payments, farm products consumed directly in farm households, gross rental value of farm dwellings, and the net change in farm inventories during the year.

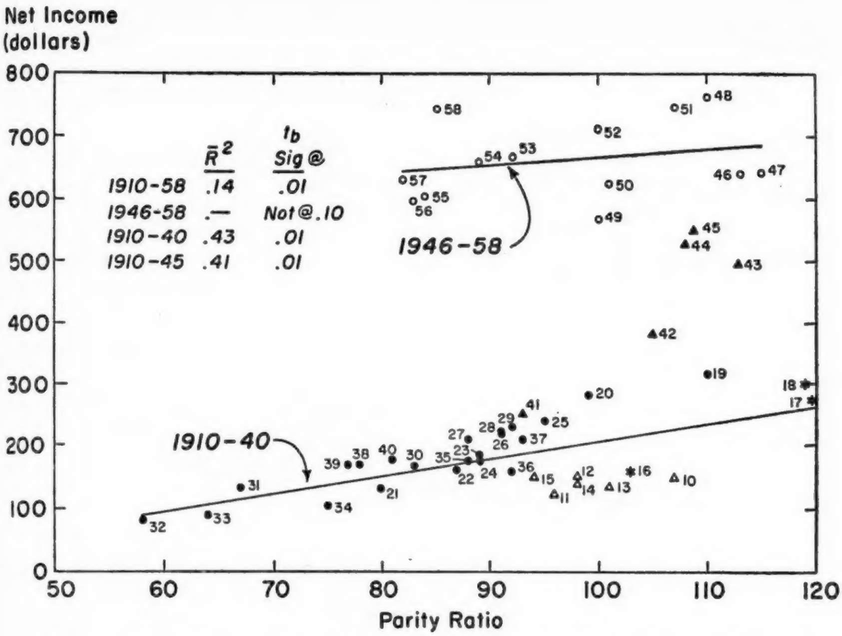


FIG. 1. COMPARISON WITH PER CAPITA NET AGRICULTURAL MONEY INCOME OF THE FARM POPULATION, 1910-58.

40, 1941-45, and 1946-58, findings are presented in terms of the relationship for the pre-World War II period (1910-40) and the post-World War II period (1946-58) as well as for the entire period (1910-58).[5]

### *Comparison with Agricultural Money Income Per Capita, Per Farm, and Per Worker*

Very little relationship existed between the parity ratio and any of the measures of per unit money income from farming (per capita net agricultural income of the farm population, net income of farm operators from farming per farm, and net income of farm workers from farming per worker). Prior to World War II, the parity ratio "explained" between a third and a half of the variation in the three per unit money income measures, depending on the measure compared. However, for the period since World War II, the parity ratio explained practically none of the variation

[5] The 1910-20 period stands out as a separate period for some net income measures and time periods, but not for others. If the 1910-20 years were dropped from the 1910-40 period, correlation between the parity ratio and the net *money* income measures (per unit or aggregate) would be increased; however, correlation between the parity ratio and the net *real* income measures would not be increased. If the 1910-20 years were dropped from the 1910-58 period, correlation would be increased somewhat for all income measures considered. For the period 1921-58, the relationship between the parity ratio and the net income measures considered would appear to be curvilinear rather than linear.

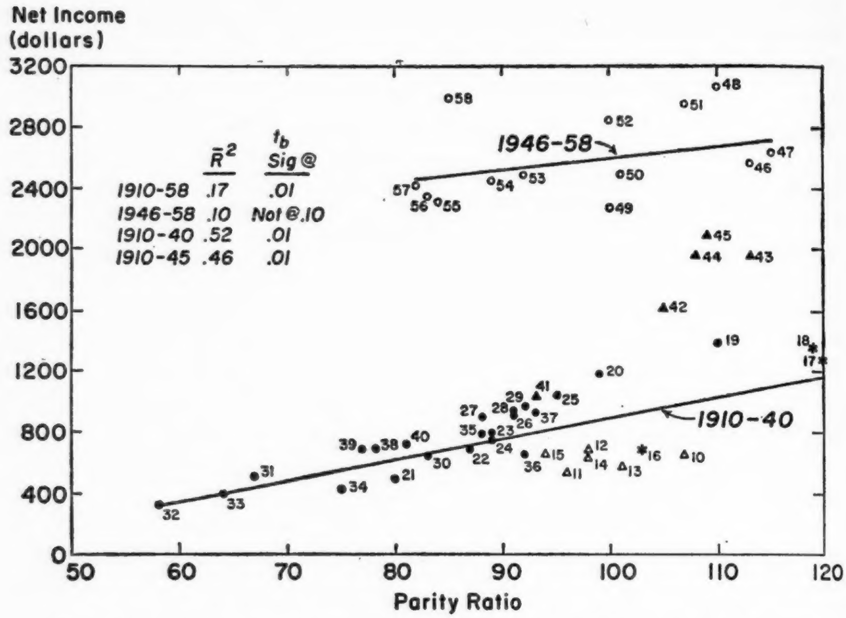


FIG. 2. COMPARISON WITH NET MONEY INCOME OF FARM OPERATORS FROM FARMING PER FARM, 1910-58.

in any of these measures. These relationships are shown in Figures 1, 2, and 3. The coefficients of determination, $\bar{R}^2$, (adjusted for degrees of freedom) are shown in each chart, along with the levels of significance (by $t$-test) at which the $b$ (slope) values of the regressions differ from zero. These statistics for all of the correlations are brought together for comparison in Table 1, in the summary section.

### *Comparison with Agricultural Real Income Per Capita, Per Farm, and Per Worker*

More relationship existed between the parity ratio and real income from farming per unit than existed between the parity ratio and money income from farming per unit, especially for the post-World War II period. For this period, the parity ratio explained up to two-thirds of the variation in real income per unit vs. almost none of the variation in money income per unit. However, for the 1910-58 period as a whole, the parity ratio gave a poor indication of the level even of real income per unit, as it explained from 25 to 44 percent of its variation. These relationships are shown in Figures 5, 6, and 7.

All of the per unit income measures rose faster relative to the parity ratio during World War II than during any other period, and they did not drop back to their previous levels after the war. As a result, the per unit

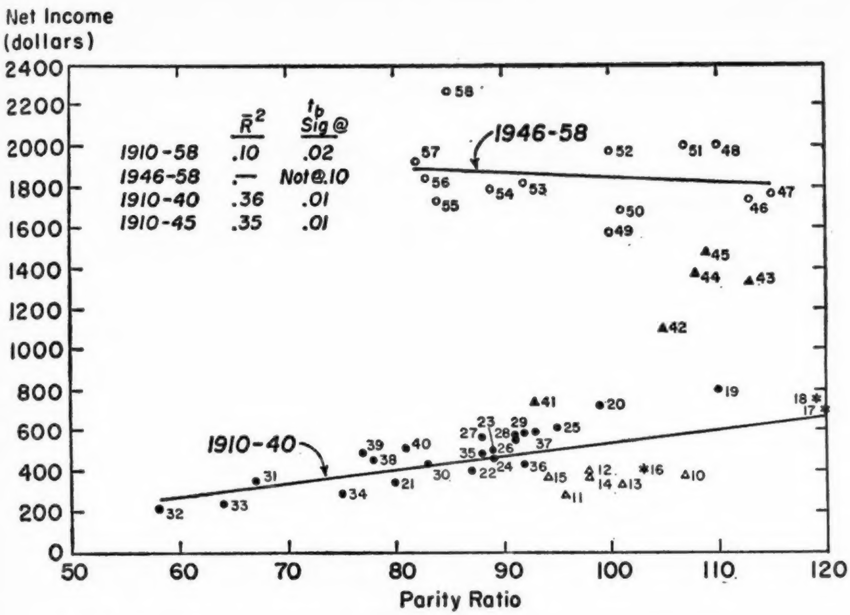


FIG. 3. COMPARISON WITH NET MONEY INCOME OF FARM WORKERS FROM FARMING PER WORKER, 1910-58.

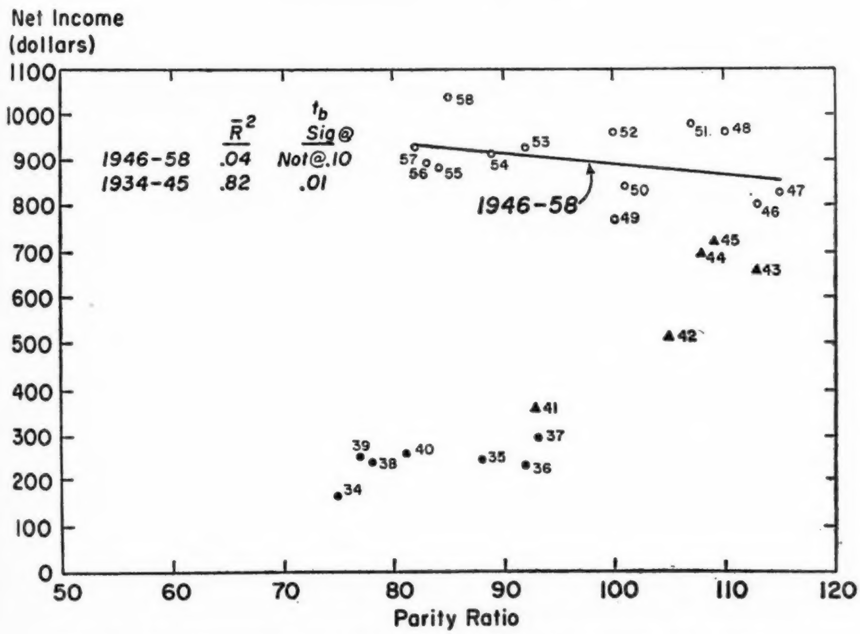


FIG. 4. COMPARISON WITH PER CAPITA NET MONEY INCOME OF THE FARM POPULATION FROM ALL SOURCES, 1934-58.

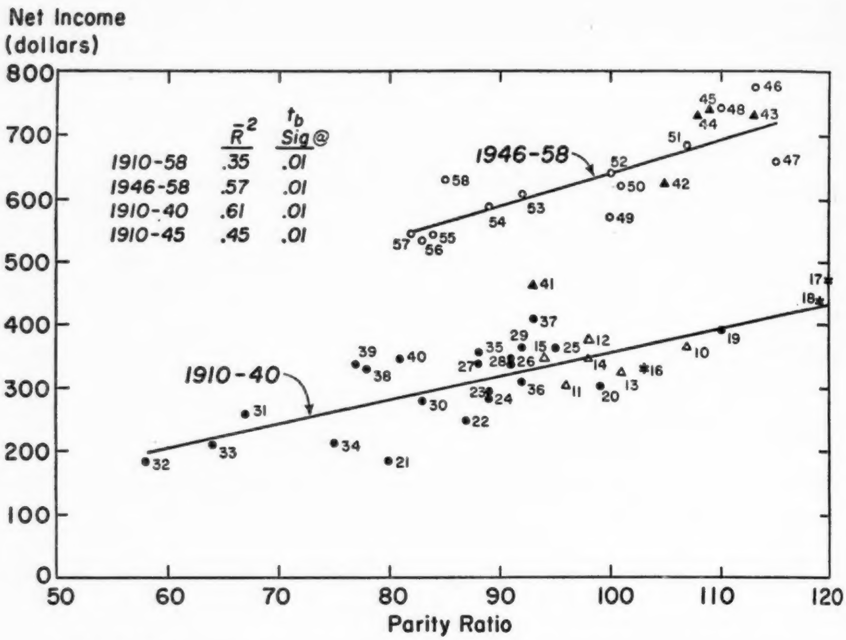


FIG. 5. COMPARISON WITH PER CAPITA NET AGRICULTURAL REAL INCOME OF THE FARM POPULATION, 1910-58.

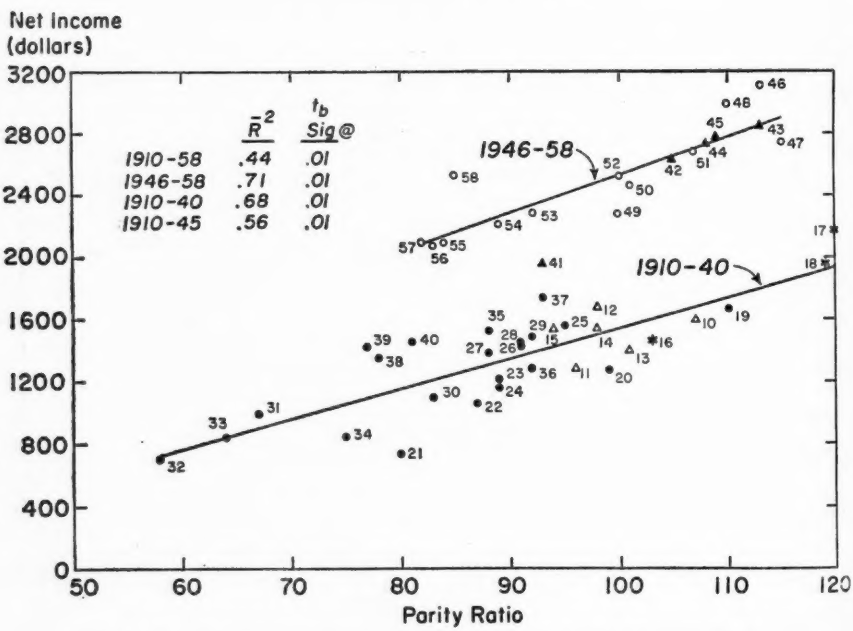


FIG. 6. COMPARISON WITH NET REAL INCOME OF FARM OPERATORS FROM FARMING PER FARM, 1910-58.

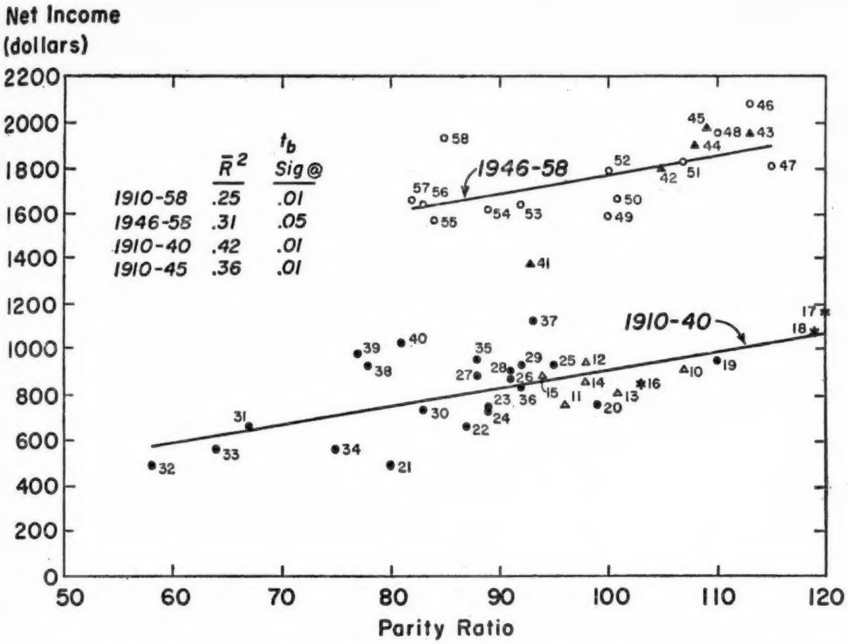


FIG. 7. COMPARISON WITH NET REAL INCOME OF FARM WORKERS FROM FARMING PER WORKER, 1910-58.

real income from farming associated with a given parity ratio has been at a level which is between 1.5 and 2 times as high since World War II as it was prior to World War II. This difference in levels between periods contributed substantially to the low correlation found between the parity ratio and the per unit income measures.

Although a change in the parity ratio was associated with a *greater absolute* change in per unit real income after World War II than prior to World War II, it was associated with a *smaller percentage* change.

Of the three measures of real income, correlation of the parity ratio was highest with income per farm, next highest with income per capita, and lowest with income per worker. Differences in the correlation with these measures came mostly from differences in reductions in number of farms, number in the farm population, and number of workers. From 1910 to 1958 the number of farms decreased 26 percent, the farm population decreased 33 percent, and the number of farm workers decreased 44 percent.

*Comparison with Aggregate Agricultural Income*

More relationship existed between the parity ratio and the aggregate net income measures, real or money, than existed between the parity ratio and the per unit net income measures which are derived from the aggregates. This was especially pronounced for the money income measures in

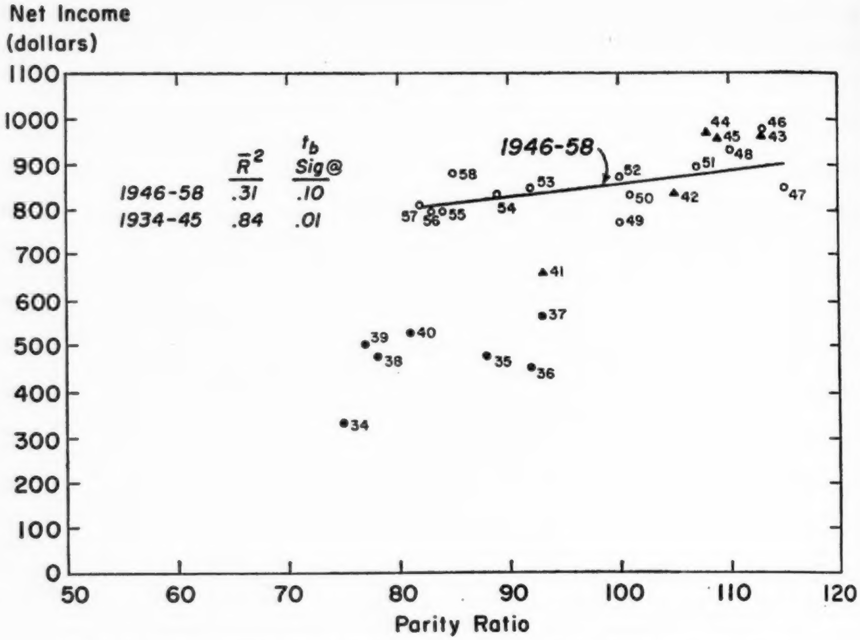


FIG. 8. COMPARISON WITH PER CAPITA NET REAL INCOME OF THE FARM POPULATION FROM ALL SOURCES, 1934-58.

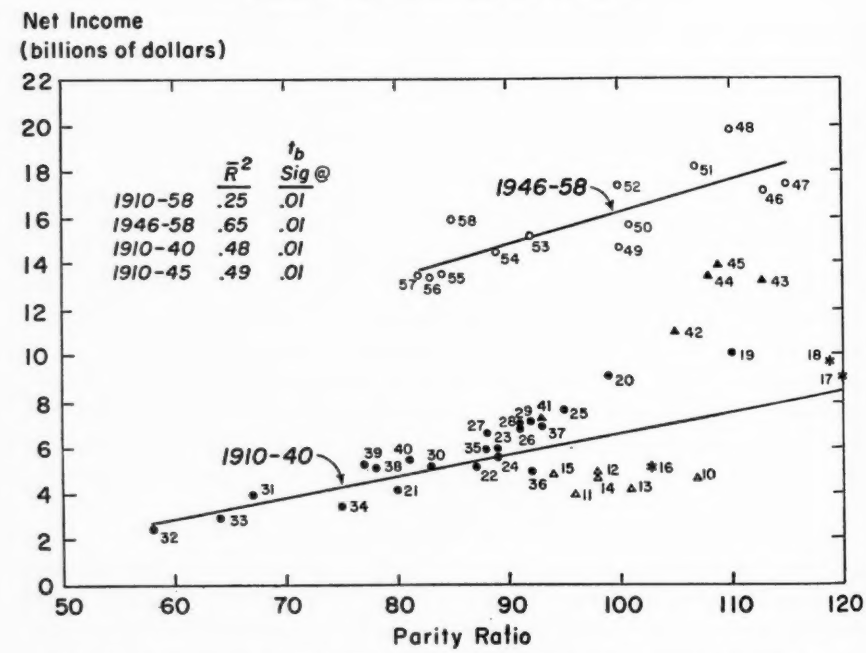


FIG. 9. COMPARISON WITH AGGREGATE NET AGRICULTURAL MONEY INCOME OF THE FARM POPULATION, 1910-58.

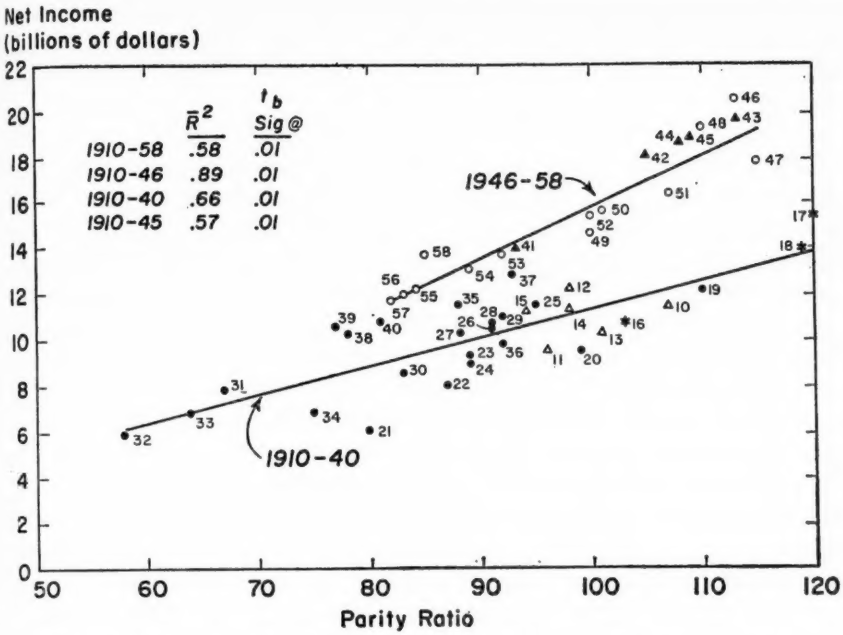


FIG. 10. COMPARISON WITH AGGREGATE NET AGRICULTURAL REAL INCOME OF THE FARM POPULATION, 1910-58.

the post-World War II period. In this period the parity ratio explained about two-thirds of the variation in aggregate money income versus almost none of the variation in per unit money income. The only cases where the parity ratio explained as much of the variation in a per unit measure as in the comparable aggregate measure were per farm money income, 1910-40, and per farm real income, 1910-40. These exceptions resulted from the number of farms remaining fairly constant during the period.

Aggregate real income moved more closely with the parity ratio than did aggregate money income. For the 1910-58 period, the parity ratio explained over half of the variation in real income from farming versus one-fourth for money income. For the 1946-58 period, the comparable figures were 89 percent versus about 65 percent. These relationships for money and real income of the farm population are shown in Figures 9 and 10. Income of farm operators and income of farm workers differ from income of the farm population only by addition or subtraction of wages, and have almost exactly the same relationship with the parity ratio.

A higher level of aggregate real income was associated with a given parity ratio since World War II than prior to World War II; however, this spread between periods is not as great for the aggregate measures as the spread found for the per unit measures. Contrary to the relationship found for the per unit measures, a change in the parity ratio was assoc-

iated with a slightly greater percentage change in aggregate real income from farming since World War II than was the case prior to World War II.

*Comparison With Income From All Sources*

Less relationship existed between the parity ratio and per unit income of the farm population *from all sources* (see Figures 4 and 8) than existed between the parity ratio and per unit income of the farm population *from agricultural sources only*. In the case of per capita money income from all sources, although the parity ratio declined after World War II, per capita money income from all sources rose. In the case of per capita real income, 1946-58, the parity ratio explained only one-third of the variation in income from all sources versus two-thirds of the variation for income from agricultural sources only. About the same statistics were obtained for aggregate money income from all sources, 1946-58, versus aggregate money income from agricultural sources only. Only in the case of aggregate real income, 1946-58, did inclusion of income from non-farm sources have little effect on correlation with the parity ratio. The parity ratio explained 87 percent of the variation in this measure for the 1946-58 period.

Although data on income from non-farm sources is available only since 1934, they suggest that a reduction in correlation would be true for the per unit income measures for the whole period 1910-58.

*Application*

It is quite likely that the parity ratio would more closely reflect the average net income of the farms, the farm population, and the farm workers that remained in agriculture for a long period of time, than it did for the groups actually studied.

Data over an extended period are not available on the income for these sub-groups remaining in agriculture. It is well known, however, that the average income of a group rises when members with less than average income leave the group even though the income of each individual remains the same. A similar situation may have had considerable effect on income per unit, as there was a considerable reduction in number of farms, number of the farm population and number of workers from 1935 to 1958. That such a situation did have an effect on computed average income, at least for the 1945-58 period is indicated by the following statements of Koffsky and Grove: "(1) The reduction in number of farms since 1947, some 15 percent for all farms, was concentrated in the low production farms, which declined about a fourth. . . . (2) The decline in net farm income per farm (including the value of inventory change) for both high production farms and low production farms has been greater than the

average reduction of some 12 percent for all farms since 1947-49. . . ."[6]

A lower net income for the 1946-58 period would have the effect of increasing correlation between the parity ratio and net income for both the 1946-58 period and the 1910-58 period. It would increase correlation for the latter period due to narrowing the spread which existed between the income associated with a given parity ratio prior to World War II and that associated with the same parity ratio after World War II. This spread would be further reduced if (due to migration out of agriculture being concentrated among members with below average income) the income of members remaining in agriculture did not rise as fast during World War II as the calculated average.

### *Summary and Conclusions*

The findings of this study are summarized in Table 1. The following general conclusions can be drawn:

(1) The parity ratio is a good indicator of the level of *aggregate* net real income from farming. It is a poor indicator of *per unit* (per capita, per farm, or per worker) net real income from farming. (Unfortunately, the parity ratio is generally used as an indicator of the level of per unit rather than aggregate net real income.)

(2) The parity ratio is a much better indicator of the level of net *real* income, per unit or aggregate, than of net *money* income, per unit or aggregate.

(3) The relationship between the parity ratio and all of the net income measures considered changed during a period centering on World War II. Since World War II, a given parity ratio has been associated with a higher net income than it was prior to World War II.[7] For example a parity ratio of 90 was associated with about a $320 per capita net real income from farming for the period prior to World War II, and about a $590 per capita net real income from farming since World War II. This change in levels considerably lowered correlation between the parity ratio and the net income measures for the 1910-1958 period.

(4) The parity ratio is a much better indicator of the level of per capita

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[6] Koffsky, Nathan M., and Grove, Ernest W., "The Current Income Position of Commercial Farms," *Policy for Commercial Agriculture,* U. S. Congress, Joint Economic Committee, Nov. 22, 1957, p. 84.

[7] This same point is made for real income per worker by D. Gale Johnson in his article, "Farm Prices, Resource Use and Farm Income," *Policy For Commercial Agriculture, op. cit.* In this article he deals with the relationship between the level of farm product prices and the returns to agricultural resources and includes the same measure of deflated net income per farm worker that is used here.

TABLE 1. SUMMARY OF THE PARITY RATIO AND NET INCOME CORRELATIONS

| Income Measure | 1910–58 | | 1946–58 | | 1910–40 | | 1910–45 | |
|---|---|---|---|---|---|---|---|---|
| | $\bar{R}^2$ | $t_b$[1] | $\bar{R}^2$ | $t_b$[1] | $\bar{R}^2$ | $t_b$[1] | $\bar{R}^2$ | $t_b$[1] |
| *Unadjusted for Purchasing Power* | | | | | | | | |
| Per Capita Net Agricultural Income of the Farm Population | .14 | (1) | — | NS | .43 | (1) | .41 | (1) |
| Net Income of Farm Operators From Farming Per Farm | .17 | (1) | .10 | NS | .52 | (1) | .49 | (1) |
| Net Income of Farm Workers From Farming Per Worker | .10 | (2) | — | NS | .36 | (1) | .35 | (1) |
| Per Capita Net Income of the Farm Population From All Sources | | | .04 | NS | | | | |
| *Adjusted for Purchasing Power* | | | | | | | | |
| Per Capita Net Agricultural Income of the Farm Population | .35 | (1) | .65 | (1) | .61 | (1) | .45 | (1) |
| Net Income of Farm Operators From Farming Per Farm | .44 | (1) | .71 | (1) | .68 | (1) | .56 | (1) |
| Net Income of Farm Workers From Farming Per Worker | .25 | (1) | .31 | (5) | .42 | (1) | .36 | (1) |
| Per Capita Net Income of the Farm Population From All Sources | | | .31 | (5) | | | | |
| *Aggregate Unadjusted For Purchasing Power* | | | | | | | | |
| Net Agricultural Income of the Farm Population | .25 | (1) | .65 | (1) | .48 | (1) | .49 | (1) |
| Net Income of Farm Operators From Farming | .26 | (1) | .66 | (1) | .50 | (1) | .51 | (1) |
| Net Income of Farm Workers From Farming | .23 | (1) | .63 | (1) | .46 | (1) | .48 | (1) |
| Net Income of the Farm Population From All Sources | | | .33 | (5) | | | | |
| *Aggregate Adjusted For Purchasing Power* | | | | | | | | |
| Net Agricultural Income of the Farm Population | .58 | (1) | .89 | (1) | .66 | (1) | .57 | (1) |
| Net Income of Farm Operators From Farming | .59 | (1) | .89 | (1) | .66 | (1) | .59 | (1) |
| Net Income of Farm Workers From Farming | .57 | (1) | .89 | (1) | .66 | (1) | .57 | (1) |
| Net Income of the Farm Population From All Sources | | | .87 | (1) | | | | |

[1] $t_b$ values:
(1) Significantly different from zero at the .01 probability level.
(2) Significantly different from zero at the .02 probability level.
(5) Significantly different from zero at the .05 probability level.
NS Not significantly different from zero at the .10 probability level.

*agricultural* income of the farm population than it is of per capita income of the farm population *from all sources,* real or money.

(5) Of the three per unit net agricultural income measures considered, the parity ratio gives the best indication of the level of income per farm, then of income per capita, and the poorest of income per worker.

Thus, if the well-being of farmers in general is expressed by the per capita, per farm, or per worker net income, real or money, then the parity ratio (a measure developed when the farm population was fairly static and income from non-farm sources was low) is a poor indicator of the general well-being of farmers.

# SUPPLY OF DAIRY PRODUCTS BY IOWA FARMERS[1]

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*Iowa State University of Science and Technology and The Agricultural Enquiry Committee of Ontario*

THE purpose of this paper is to report the results of a study of the total supply of milk by Iowa farmers. The objective of the study was structural analysis—measurement of factors determining milk supply. Although the results should be useful in forecasting, finding good forecasting equations was not one of our specific objectives.

Annual time series data covering the state of Iowa were studied by multiple regression analysis. Within the last few years Halvorson has used time series data to study total United States milk supply[2] and to study milk production per cow in the United States and in each of six regions.[3] Brandow has analyzed time series data for several groups of states and for some individual states in an effort to find the determinants of dairy cow numbers and of milk production per cow.[4]

## *Economic Model*

Our economic model differs somewhat from the models used by Halvorson and by Brandow. Start with the definition

$$Q = N\phi \tag{1}$$

where $Q$ = total output, $N$ = number of cows milked and $\phi$ = average output per cow. Thus it would be possible to estimate number of cows

$$N = a_0 X_1^{a_1} X_2^{a_2} \cdots X_n^{a_n}, \tag{2}$$

and output per cow

$$\phi = b_0 Z_1^{b_1} Z_2^{b_2} \cdots N^{b_N}, \tag{3}$$

and multiply them to obtain estimates of total output. Some variables might affect both number of cows and output per cow; i.e., some variables appearing as $X_i$ in (2) would also appear as $Z_i$ in (3). Substituing (2) into (3) provides another equation for the study of $\phi$

$$\phi = b_0 a_0^{b_N} Z_1^{b_1} Z_2^{b_2} \cdots X_1^{a_1 b_N} X_2^{a_2 b_N} \cdots X_n^{a_n b_N}. \tag{4}$$

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[1] Journal Paper No. J-3971 of the Iowa Agricultural and Home Economics Experiment Station, Ames, Iowa, Project No. 1318, Center for Agricultural and Economic Adjustment cooperating.

[2] "The Response of Milk Production to Price," *J. Farm Econ.*, 40:1101-13, Dec. 1958.

[3] "The Supply Elasticity for Milk in the Short Run," *J. Farm Econ.*, 37:1186-97, Dec. 1955.

[4] *Changes in Milk Production in the United States, 1924-51,* Pa. Agr. Expt. Sta. Prog. Rept. No. 97, Feb. 1953.

Multiplying both sides of (3) by $N$ gives another equation for the analysis of $Q$,

(5) $$Q = N\phi = b_0 Z_1^{b_1} Z_2^{b_2} \cdots N^{1+b_N}.$$

Substituting (2) into (5) and consolidating yields another expression for $Q$,

(6) $$Q = a_0^{1+b_N} b_0 X_1^{a_1(1+b_N)} X_2^{a_2(1+b_N)} \cdots X_n^{a_n(1+b_N)} Z_1^{b_1} Z_2^{b_2} \cdots .$$

If (2) and (3) are not linear in logarithms, (4), (5) and (6) are not so neat.

In his 1958 study Halvorson used a model similar to (6).[5] His earlier study had used a model like equation (3).[6] Brandow used (4) and (2).[7] We chose to work with models (2) and (5), and slight variations thereof. For $N$ we used January 1 cow numbers rather than average number milked during the year; one reason for this was to obtain a predetermined variable for $N$ in equation (5).

Most of the variables used (the $X_i$ and $Z_i$) require no discussion; but it may be worthwhile to consider some of the others in detail.

The static theory of the firm suggests the inclusion of such variables as dairy-livestock price ratio, dairy–feed-grain price ratio, etc., in a dairy supply analysis. Such variables were included in our analysis.

Farmers have to make decisions and plans on the basis of expected prices. If they use information on aggregate feed supplies in relation to aggregate number of livestock in their estimation of expected prices, then feed supplies and livestock inventories affect the level of dairy production.[8] We therefore included variables to represent number of animal units on farms and the supplies of grain and roughage.

Also, it is possible that some farmers may plant feed grains with the intention of feeding all or most of their harvest to their own livestock; i.e., they view grains as intermediate products to be fed to livestock. Farmers who have such intentions at the beginning of a year will govern their feeding rates during the year by the supply of feed in relation to the number of animal units to be fed. Variations in the dairy-feed or livestock-feed price ratios during the year will have limited effect on their feeding operations.

It has been proposed that a small scale dairy enterprise is nearly independent of other enterprises in production. In this event, it might be expected that many farms would maintain a small dairy herd. This would lead to a positive relationship between number of farms and number of

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[5] Cf. footnote 2.

[6] Cf. footnote 3.

[7] Cf. footnote 4.

[8] Nerlove has suggested ". . . we might wish to take account of the influence of anticipated changes in livestock numbers on the expected price of corn." (See "Estimates of the Elasticities of Supply of Selected Agricultural Commodities," *J. Farm Econ.*, 38:502, fn. 11, May 1956.) We are using livestock numbers rather than changes therein.

dairy cattle.[9] Number of farms was included in some regressions to test this hypothesis.

Farmers may attempt to limit income variability. Dairying is one way of achieving this, since it provides low income variation. This suggests that changes in the supply of dairy products would be positively correlated with changes in farm income variability. To test this hypothesis, various measures of the variability of farm income were used in the analysis.[10]

There is also the possibility that the supply of dairy products is related to the level of farm income as contrasted with its variability. The senior author has previously attempted to show the theoretical relation of supply to farm income level.[11] It was shown that the relevant income variable may not be the absolute level of real farm income but the amount of the decline in farm income from a previous peak level. One variable was used to test this hypothesis.

Deflated gross income per farm was also included to determine whether there is a relationship between dairy supply and the level of farm income. It has been hypothesized that farmers tend to produce more as income falls.

### *Statistical Model*

The analytical technique used was a common one—application of least squares to annual time series data. Not enough is known about the supply of dairy products to argue strongly that a simultaneous equations estimation procedure would be superior to least squares; it may be. In the exploratory stages of a study, when there are many alternative hypotheses to be tested, the economy of least squares is a strong recommendation for its use.

### *Research Procedure*

Selection of the procedure was conditioned by the existence of three different problems: (1) uncertainty as to the form of the relationships—linear, quadratic, linear in logs, etc.; (2) the multiplicity of plausible hypotheses to be tested—too many to include in one regression equation; and (3) the possibility of using any one of several different variables as the empirical counterpart of a generic variable whose inclusion is suggested by theory, e.g., feed grain supply or income variability.

The first problem was partially solved by estimating each one of an initial set of equations with data in four forms: arithmetic (A), logarithmic (L), first differences of arithmetic values (FDA) and first differences

[9] Winter, George, "Factors Affecting Numbers of Dairy Cows on Iowa Farms," Unpub. M.S. thesis, Iowa State Univ. Libr., Ames, Iowa, 1958, pp. 15-16, 34. Results presented here on determinants of cow numbers represent an expansion of this thesis.

[10] *Ibid.*, pp. 23-25.

[11] "Farm Income and the Supply of Agricultural Products," *J. Farm Econ.*, 39:865-80, Nov. 1957.

of logarithms (FDL).[12] In the equations with $Q$ dependent, the use of L and FDL seemed to give superior results, on both economic and statistical grounds, to the use of A and FDA. L and FDL were therefore used in subsequent regressions. In equations with $N$ dependent, on the other hand, neither form seemed superior to the other. For the sake of convenience, A and FDA were used in subsequent regressions.[13]

Because of the existence of problems (2) and (3), it was not feasible to include all hypotheses and all variables in the initial set of equations.

Variables which were consistently significant in these equations were retained, those which were consistently nonsignificant were replaced by new variables and the set of revised equations was fitted. Variables which were consistently nonsignificant in the second set of equations were replaced and the process was continued. When a variable was neither consistently significant nor consistently nonsignificant, it was combined with different sets of independent variables and was used in more regressions. In some cases, results obtained at one stage suggested hypotheses to be tested at later stages of the research.

An experimental procedure such as this is subject to criticism, as is made clear by Christ.[14] In order to give the reader some protection against the danger Christ mentions, i.e., ". . . a bias in favor of deciding that the parameters are significantly different from zero," the conclusions presented below are not taken only from the last few or from the "best" equations fitted. They are based on all of the equations. This furnishes only partial protection against a Type I error, i.e., of rejecting a true null hypothesis.

*Conclusions*

Table 1 summarizes the results. A complete list of the exact definition of each variable and the sources used in constructing each series would entail considerable space. A brief definition of each variable will be presented below in the discussion of the results. So far as possible, mnemonic notation will be used. Current year values will be indicated by the absence of any time subscript. For flow variables, the absence of a time subscript indicates the rate of flow over the current year. For stock variables, the absence of a time subscript indicates the stock existing at the begin-

[12] Throughout the remainder of this paper we will use these four abbreviations—A, L, FDA, FDL.

[13] One could use the Durbin-Watson $d$ statistic as one basis for determining which data form to use. We paid little attention to $d$ statistics at any stage of our study. Recent research indicates that this is a weak test with a distressingly high probability of a type II error, i.e., of accepting a false hypothesis. George W. Ladd, "Monte Carlo $d$ Statistics," unpub. research. Wayne A. Fuller and James E. Martin, "The Effects of Autocorrelated Errors on the Statistical Estimation of Distributed Lag Models," *J. Farm Econ.*, 43:71-82, Feb. 1961.

[14] "Aggregate Economic Models, A Review Article," *Amer. Econ. Rev.*, 46:400-01, June 1956.

TABLE 1. ELASTICITIES OF IOWA DAIRY COW NUMBERS AND IOWA MILK PRODUCTION WITH RESPECT TO RELEVANT VARIABLES

| Explanatory variable[a] | | Jan. 1 number of dairy cows $N$ | Milk Production $Q$ |
|---|---|---|---|
| Jan. 1 milk cow numbers 1 year previous | $N_{t-1}$ | 0.3[b]<br>0.8[c] | |
| Number of farms | $F$ | 1.0[d]<br>0.0[e] | 0.65[d]<br>0.0[e] |
| Average production per cow | $\phi$ | −0.9 | −0.58 |
| Lagged moving variance of deflated gross farm income | $V_G$ | 0.2 | 0.13 |
| Ratio of dairy prices received last year to all farm prices received last year | $P_{Rt-1}$ | 0.1 | 0.06 |
| Ratio of dairy prices received last year to beef prices | $P_{Bt-1}$ | 0.1 | 0.06 |
| Feed grain supply | $C''$ | | 0.1 |
| Number of roughage-consuming animal units | $U_{r-d}$ | | −0.1 |
| Supply of hay and silage | $HS$ | | 0.1 |
| Jan. 1 numbers of milk cows and heifers | $N'$ | | 0.65 |

[a] See following text for more complete definitions of variables.
[b] FDA data.
[c] A data.
[d] 1926–56.
[e] 1937–56.

ning of the current period. An $i$-year lag is indicated by the subscript, $t$-$i$. Almost all variables refer to Iowa; the few exceptions will be noted in the definitions.

*Number of dairy cows (N dependent)*

$N$ = number of cows and heifers 2 years old and older kept for milk as of Jan. 1.

1. The coefficient of $N_{t-1}$ was significant in every equation fitted to A or L and in many of the equations fitted to FDA or to FDL. The use of differences yielded smaller estimates of the elasticity of $N$ with respect to $N_{t-1}$ than did the use of nondifferenced data, 0.3 and 0.8 respectively, at the 1926-56 mean values of the variables. One can do quite well at predicting $N$ by using only the simple regression of $N$ on $N_{t-1}$. Their simple coefficient of determination is 0.92.

The coefficient of $N_{t-1}$ may represent the adjustment coefficient which differentiates long-run from short-run elasticities.[15] It may represent a

[15] Marc Nerlove, *The Dynamics of Supply: Estimation of Farmers' Response to Price*, Baltimore: The Johns Hopkins Press, 1958. pp. 59-66.

coefficient of price expectations.[16] It may be a manifestation of serial correlation in the residuals. Or it may represent a combination of these. Assume the equation $N_t = b_0 + b_1X_{1t} + b_2X_{2t} + b_3N_{t-1}$. According to the long-run elasticities hypothesis, the elasticities are

$$b_1\overline{X}_1/(1 - b_3)\overline{N} \quad \text{and} \quad b_2\overline{X}_2/(1 - b_3)\overline{N}.$$

Because of the different possible interpretations of $b_3$, the conclusions presented below regarding $X_1$ and $X_2$ are based solely on the estimates of $b_1$ and $b_2$.

2. $F$ = number of farms.

Over the period 1926-56, a decrease of 1,000 in $F$ was accompanied on the average by a 6,400 head decrease in $N$. At the mean values, this represents an elasticity of +1.0. The coefficient of $F$ is not significant in any of the equations fitted to 1937-56 data. $F$ was included to test the hypothesis that many farms maintain small dairy operations which are nearly independent of other enterprises in production. As agriculture has become more specialized and more mechanized over time, it is possible that the number of farms on which this independence prevails has declined. This would explain why $F$ was significant for the longer sample period but not for the shorter. This would mean that $N$ was dependent on $F$ at one time but is no longer so dependent.

3. $\phi$ = average milk production per cow during the calendar year.

A +100 pound change in $\phi$ is associated with a decrease of 26,600 head in $N$. At the 1926–56 mean values, this represents an elasticity of $N$ with respect to $\phi$ of $-0.9$.

The coefficient of $\phi$ was significant in every A or L equation; it was nonsignificant in every FDA and FDL equation. The most reasonable explanation for this seems to lie in the effect of first differencing on errors of measurement. Let $\phi_m$ = the measured value of output per cow, i.e., the variable used in the regressions; $\phi_a$ = the accurately measured or true value of output per cow; and $\phi_e$ = error of measurement in $\phi_m$. Define $\phi_m = \phi_a + \phi_e$. Let $r$ = simple correlation between $\phi_e$ and $\phi_{et-1}$. Then, approximately, var $(\Delta\phi_e) = 2(1 - r)$ var $(\phi_e)$; consequently, var $(\Delta\phi_e) >$ var $(\phi_e)$ if $r < 0.5$.

Economists usually like to think that the autocorrelation in the errors of measurement in their data is small. If they are justified in this belief, first differencing increases the variance of the error of measurement. The presence of such errors in a variable tends to bias its coefficient toward zero. Then var $(\Delta\phi_e)$ may be large enough to cause sufficient bias in the coefficients of $\Delta\phi_m$ to result in nonsignificance whereas var $(\phi_e)$ may not be large enough to cause sufficient bias to result in nonsignificance of the coefficients of $\phi_m$.

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[16] *Ibid.*, pp. 46-59.

4. $I_G$ = gross income per Iowa farm divided by the United States average index of all prices paid by farmers.

$I_N$ = realized net income similarly deflated.

$I_{NM}$ = maximum value of $I_{Nt-i}$, $i = 2, \ldots, 6$.

$I_d = I_{Nt-1} - I_{NM}$.

We found no evidence of a relation between $N$ and the level of farm income. $I_G$, $I_{Gt-1}$ and $I_{Gt-2}$ were used. In no case was the coefficient significantly different from zero; the coefficient ranged in size from 1.3 to 1.6 times the size of the standard error. $I_d$, $I_{dt-1}$ and $I_{dt-2}$ were each used once to test the hypothesis that dairy supply is related to the deviation of real income from the previous peak level of real income. The coefficients were smaller than their standard errors.

5. $V_G$ = variance of $I_G$ during the previous 4 years.

$V_N$ = variance of $I_N$ during the previous 4 years.

Our results lead to the acceptance of the hypothesis that Iowa farmers react to changes in income variability by changes in the same direction in the sizes of their dairy herds. The coefficient of $V_G$ was significant in all 11 equations in which it was used. The variance of undeflated gross farm income was used once and was significant. The coefficient of $V_N$ was nonsignificant the two times it was used. At 1926-56 mean values, the elasticity of $N$ with respect to $V_G$ is $+0.2$.[17]

6. $P_D$ = Laspeyres index of prices received for dairy products, 1924-28 = 100.

$P_B = P_D$ divided by an index of beef prices, 1924-28 = 100.

Variations in $P_{Bt-1}$ have a significant effect on $N$. Over the period 1926-56, a $+1.0$ unit change in $P_{Bt-1}$ was followed by a $+1{,}000$ head change in $N$. This represents an elasticity of $+0.1$ at the mean values.

7. $P_R = P_D$ divided by the index of prices received for all farm products, 1924-28 = 100.

$P_{Rt-1}$ is useful in explaining variations in $N$. A $+1.0$ unit change in $P_{Rt-1}$ results in a 1,650 head increase in $N$. The elasticity is $+0.1$ at the mean values of the variables. We did not thoroughly investigate the possibility that $P_{Rt-1}$ is significant only because the price in the denominator contains beef price and beef price has a significant effect on $N$. However, a few computations we carried out suggested that this is, in fact, the case.

8. $U_r$ = Number of roughage-consuming animal units on farms during the calendar year.

$U_{r-d} = U_r$ minus the dairy stock component of $U_r$.

$U_{g-d}$ = Number of grain-consuming animal units on farms during the calendar year minus the number of grain-consuming animal units in the form of dairy stock.

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[17] One referee suggested the use of undeflated non-dairy gross income to judge the responsiveness of farmers to instability in non-dairy enterprises.

A number of other variables which were used contributed nothing to our understanding of variations in $N$. $U_r$ and $U_{r-d}$ were used in a total of 11 equations and their coefficients were nonsignificant in every one. The coefficient of the dairy-price–farm-wage-rate ratio was nonsignificant in all eight equations in which it was used. The coefficients of $U_{g-d}$ and $U_{g-d\ t-1}$ were nonsignificant. The coefficient of $U_{g-d\ t-2}$ was significant at the 10 percent level the one time it was used, but it was positive whereas we expected it to be negative. The coefficient of feed grain supply, $C_{t-2}$ (defined below), was significant at the 5 percent level one time out of three and its coefficient was positive each time.

*Iowa Farmers' Supply of Milk (Q Dependent)*

$Q$ = quantity of whole milk equivalent produced on Iowa farms.

1. The elasticity of $Q$ with respect to the number of roughage-consuming animal units, $U_{r-d}$, is $-0.1$.

2. $HS$ = hay and roughage supply.

The coefficient of $HS$ was positive but nonsignificant in every FDA or FDL equation in which it was included. $HS$ was included in five A or L equations. In four of them its coefficient was significant at the 5 or 10 percent level; in the fifth it was significant at the 11 percent level. $HS$ contains sizeable errors of measurement since it excludes stover; fodder; sorghum silage; and feed obtained from pasture, cornfields and stubble fields. By the same argument used in connection with $\phi$, above, these errors of measurement may account for the finding of higher levels of significance for the coefficients of $HS$ than for the coefficients of $\Delta HS$.

3. $H$ = heifers 1 to 2 years old kept for milk, Jan. 1.

$$N' = N + \frac{1}{2}H.$$

The elasticity of $Q$ with respect to $N'$ is $+0.65$. Although total production is positively related to $N'$, output per cow is negatively related to $N'$. The estimated value of $1 + b_N$ in equation (5) is $+0.65$. Hence, $b_N$ in equation (3) is on the order of $-0.35$.

$N$ was used in three equations. Its coefficient was never significant. In contrast, the coefficient of $N'$ was always significant.

4. $P_I'$ = Fisher's Ideal Index of prices received for dairy products, i.e., the geometric mean of the Paasche and Laspeyres indexes, 1937-41 = 100.

$P_L'$ = Fisher's Ideal Index of prices received for livestock and livestock products other than dairy products, 1937-41 = 100.

$$P_L = P_I'/P_L'$$

$P_G = P_I'$ divided by the USDA index of prices received by Iowa farmers for feed grains.

$P_W = P_I'$ divided by the USDA index of farm wage rates paid in Iowa.

Given $N'$, price variables are of little use in explaining variations in $Q$. The only one which seems to be related to $Q$ is $P_G$. The coefficient of $P_G$ always has the expected sign (positive) and is significant at the 10 percent level in three of the eight equations in which it was used. The coefficients of $P_L$ and lagged $P_L$ were never significant. In seven equations, the coefficients of $P_W$ and lagged $P_W$ were significant only once.[18]

5. Prices, however, do affect Iowa dairy supply. As shown previously, $P_{Bt-1}$ and $P_{Rt-1}$ affect $N$. The elasticities are +0.1. Some other equations which were estimated indicated that the elasticity of $N'$ with respect to $P_{Rt-1}$ did not differ appreciably from this value. From equation (5) and the estimated elasticities,

$$\frac{\partial \log Q}{\partial \log P_{Rt-1}} = \frac{\partial \log Q}{\partial \log N'} \frac{d \log N'}{d \log P_{Rt-1}} = 0.65 \times 0.1 = 0.065.$$

Since the elasticity of $N'$ with respect to $P_{Bt-1}$ is also 0.1, the elasticity of $Q$ with respect to $P_{Bt-1}$ is also 0.065.[19]

6. *Ceteris paribus* Iowa dairy production has trended upward at an average rate of 0.3 percent per year.

7. The number of grain- and roughage-consuming animal units on farms was used in four FDL equations and its coefficient was nonsignificant in every one.

8. Four feed grain supply variables were used; several different forms were used because of the impossibility of selecting *a priori* the best form. It is clear that production and Jan. 1 carry-over of feeds are both relevant. The two are not perfect substitutes since the latter can be fed at any time during the year whereas current production can affect dairy output only during the latter part of the year. Therefore, two variables measure production and carry-over separately. Two variables which do not distinguish between production and stocks were also constructed.

To construct the variables, eight series were used:

$Q_c$, $Q_o$, $Q_b$ = production of corn, oats and barley, respectively.

$S_c$, $S_o$ = Jan. 1 stocks of corn and oats on farms.

$S_c^*$, $S_o^*$ = Oct. 1 stocks of old crop corn and July 1 stocks of old crop oats on farms.

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[18] One reviewer has pointed out, "The complicating factor here is the fact that as numbers increase, the negative impact of this on production per cow tends to offset increases in production per cow which might have tended to develop out of high milk-feed price ratios. Thus, the interrelationships of numbers production per cow and total milk supplies and explanatory variables is indeed a very complex one."

[19] The elasticities of $Q$ with respect to $\emptyset$, $F$ and $V_G$ presented in Table 1 were computed using this same procedure.

Define $r_c$ and $R_c$ as

$$r_c = \frac{1}{T} \sum_t \frac{S_c^*}{S_c},$$

$$R_c = \frac{1}{T} \sum_t \frac{S_c}{S_{ct-1}^* + Q_{ct-1}}$$

Define $r_o$ and $R_o$ similarly. $R_c$ is the average proportion of old crop corn and corn production still on hand at the end of the year. $r_c$ is the average proportion of January 1 stocks still on hand at harvest time.

The four feed grain supply variables are defined as follows:

(a) $C'' = S_c + (1 - R_c)(Q_c + S_c^*) + 0.55[S_0 + (1 - R_0)(Q_0 + S_0^*)] + 0.8[0.5(Q_{bt} + Q_{bt-1})].$

(b) $C = C'' - r_c S_c - 0.55 r_o S_o$

(c) $C' = (Q_c + S_c) + 0.55(Q_o + S_o) + 0.8[0.5(Q_{bt} + Q_{bt-1})].$

(d) $C''' = C' - S_{ct+1} - 0.55 S_{ot+1}.$

$C$ and $C''$ measure production and carry-over separately; $C'$ and $C'''$ do not. $C''$ contains some double counting that $C$ does not, namely that part of $S_o$ and $S_c$ included in $S_o^*$ and $S_c^*$. $C'''$ is total supply (beginning stocks plus harvest) minus end of year carry-over.

Most of the series used in our regressions were carried back to the mid-1920's. Data on barley stocks are not available for the earlier years so an alternative measure of barley supply was used. The weights of 1.0 for corn, 0.55 for oats and 0.8 for barley are intended to approximate the average relative dairy feeding values of a bushel of each.

Several equations were fitted using $C''$ and other variables and then recomputed using $C'''$. The coefficients of both were significant at the 1 percent level in every equation and were not appreciably different. Since the value of $R^2$ was always 7 to 10 percent higher when using $C''$ than when using $C'''$, $C''$ was retained for further use. $C$, $C'$, $C/U_{g-d}$ and $C'/U_{g-d}$ were used in a few equations. Their coefficients were not significant.

A +1.0 percent change in $C''$ is accompanied by a +0.1 percent change in $Q$.

9. Seventy-three percent of the variation in the FDL of total supply can be explained by variations in the FDL of $N'$, $U_{r-d}$ and $C''$; 95 percent of the variation in the L of supply can be explained by variations in the L of $N'$, $U_{r-d}$, $C''$, $HS$ and time.

# TEMPORAL DETERIORATION OF RESEARCH DATA ON COSTS[1]

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POSSIBLY the most difficult problem faced by economists concerned with problems involving the determination of costs is the high degree of "perishability" of the data. In fact, research bulletins dealing with costs—whether they deal with problems of marketing, farm management, or resource use—are practically always out of date prior to the time they are made available for general distribution. This imposes severe limitations on the usefulness of such results.

Proponents of the budgetary or "synthetic" method claim their procedures make it relatively easy to make periodic recomputations and so reduce this perishability. Briefly stated, this "building-block" technique is developed in two steps. The first involves the determination of basic input-output relationships. These specify the physical quantities and qualities of cost factors—such as labor, supplies, and building and equipment specifications and life expectancies—required under efficient production conditions for the output of specified quantities of goods and services. The second step involves application of the appropriate cost rates to these input factors and so results in the determination of money costs for the particular process. Consequently, when cost rates change, the new rates may be substituted, arriving at different and "up-to-date" cost figures. The assumption necessary for such modification is that technology is constant and that the basic input-output relations remain unchanged.

The purpose of this paper is to discuss the application of the results of a cost study of this type and, in particular, to examine certain modifications to the results that have been made as a result of temporal changes. In this instance, an analysis was made of the cost-volume relationships for the delivery of milk to wholesale customers in California markets. These cost-volume relationships were then used as a norm for establishing volume-pricing schedules which would reflect differential costs of delivery to customers receiving different volumes.[2]

In the original study, detailed time observations were made on over 270 wholesale milk routes operating in 7 markets in the state. A total of more than 8,000 individual customer deliveries was recorded. Subsequently, the time-volume and resulting cost-volume relationships so determined were used by the California Bureau of Milk Stabilization (the agency which establishes both minimum producer and resale prices) for these markets.

[1] Giannini Foundation Paper No. 198.

[2] The results of the study and their initial application have been reported by D. A. Clarke, Jr., *Milk Delivery Costs and Volume Pricing Procedures in California*, Calif. Agr. Exp. Sta. Bul. 757 (Berkeley, 1956), 77p.

Analytically, the total cost of delivery was divided into two major components—labor and truck costs. The labor component was developed on the basis of determining time requirements for three subelements: route driving time; direct delivery time; and miscellaneous at-plant and personal time. Total route labor costs are a function of time and the prevailing wage conditions. Truck costs are more closely associated with the size and type of equipment operated.

The results of the study indicated that driving time was a function of the mileage traveled ($M$) and the number of customers served ($C$) on the route. Direct delivery time was found to be strongly influenced by the types of service combinations ($X$), but for any given $X$, could be described as a function of customer numbers ($C$), the volume of products served per customer ($V_s$), and the total route volume ($V_r$). Miscellaneous time was primarily determined by the institutional arrangements within the market which specified the functions the driver was required to perform at the plant—both before and after delivery. For any given set of such functions ($Y$), this element of total route time requirements tended to be a constant.

In general form, total route time requirements ($TT$) could be specified as:

$$TT = f(C, V_s, V_r, M \mid X, Y)$$

Since $TT$ is also given by institutional conditions—in California markets at 480 minutes per day—this can be substituted on the left side of the equation. Further, when $M$ is taken as the average mileage traveled by routes within a market and $X$ and $Y$ given by the "typical" institutional arrangements in the market, the entire expression can be formulated in terms of the highly interrelated variables—$C$, $V_s$, and $V_r$. The time requirements for any specified delivery volume can be converted into money costs by the application of the appropriate labor cost ($W$). As previously suggested, the remaining cost component—truck cost—is a function of $V_r$. For each $V_r$, then, this cost can be determined in money terms and added to labor cost to determine the total cost.

Let us now look at this formulation in terms of changes that may be expected over time. Summarizing, we have as variables within the cost elements the factors $C, V_s$, and $V_r$—specified for any given $M$, $X$, $Y$ and $W$. Adjustments for wage changes may be made merely by substituting the new value for $W$. Similarly, by relatively simple surveys, changes can be made in $M$, $X$, and $Y$ (route mileage, type of service, and institutional arrangements, respectively). The remaining factor to be considered—and that primarily discussed in the remainder of the paper—relates to the problem of making adjustments to account for changes in the value of the specific coefficients attached to the variables $V_s$, $C$, and $V_r$ (the volume delivered

per customer, the number of customers, and the total route volume, respectively), the basic input-output relationships.

In 1959, studies were made to test whether or not basic changes had occurred in the methods of delivery which would affect the underlying input-output relationships. It had been observed, for example, that a new network of freeways had sprung up around most of the markets which were involved. In some areas, union regulations had changed which specified later delivery departure hours. Both of these changes might be expected to influence the average rate of driving speed and so the coefficients relating to driving-time requirements. Furthermore, the number of large-volume supermarkets had increased and, in some instances, new and improved techniques were used for making deliveries from the truck to the final point of delivery.

For this reason, an additional 29 wholesale milk routes were observed in the Los Angeles area during the summer of 1959.[3] Other than size of sample, this study differed only in that the direct delivery time was recorded as an aggregate rather than by individual delivery functions.

*Analysis*

Each relationship was derived using basically the same procedures as used in the 1950 study. Each newly derived element was then tested under the hypothesis that the 1959 relationship was equal to the 1950 relationship. If the hypothesis were rejected, the new relationship would be used; if not, the 1950 relationship would be retained. Where the relations were derived by classical regression, appropriate test statistics were used; where relations were derived graphically, they were compared graphically.

The driving time component was divided into three subelements, and the relationships estimated by least-square regression. The first equation of each of the following sets, denoted by ($'$), represents the 1950 derived relationship; the second, that for 1959:[4]

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[3] The 1950 study in the Los Angeles area involved 111 wholesale milk routes and 2,897 deliveries. The 1959 study involved 29 routes and 424 deliveries.

[4] $R$ is the correlated correlation coefficient for the respective equations. The numbers in parentheses are the statistic

$$t = \frac{\alpha_1 + \alpha_2}{S_p\sqrt{\dfrac{1}{n_1} + \dfrac{1}{n_2}}}$$

for the corresponding set of coefficients. The numbers in brackets are the statistic

$$F = \frac{\mathcal{S}_\omega - \mathcal{S}_\Omega}{\mathcal{S}_\Omega}\,\frac{n_1 + n_2 - 2k}{k},$$

a test for homogeneity of regression, where $\mathcal{S}_\omega = NS_p^2(1 - R_p^2)$ and $\mathcal{S}_\Omega = n_1S_1^2(v - R_1^2) + n_2S_2^2(1 - R_2^2)$, in which subscript $p$ indicates pooled relations; 1, the 1950 para-

Driving time from the plant to the first stop:

$$t_1' = 5.41 + 2.08m_1' \qquad R_1' = .88,\ \bar{m}_1' = 6.52$$

$$t_1 = 8.47 + 1.57m_1 \qquad R_1 = .89,\ \bar{m}_1 = 11.74$$

$$(-19.8)\ (33.1) \qquad [6.32]$$

Driving time from the first stop to the last stop:

$$t_2' = 20.32 + 2.14m_2' + 1.01C' \qquad R_2' = .90,\ m_2' = 22.80,\ \bar{C}' = 23.64$$

$$t_2 = 18.89 + 2.38m_2 + .588C \qquad R_2 = .94,\ \bar{m}_2 = 21.35,\ \bar{C} = 14.26$$

$$(4.9) \quad (-3.7) \quad (9.6) \qquad [.83]$$

Driving time from last stop to the plant:

$$t_3' = 8.75 + 2.07m_3' \qquad R_3' = .87,\ m_3' = 9.28$$

$$t_3 = 14.02 + 1.25m_3 \qquad R_3 = .74,\ \bar{m}_3 = 13.89$$

$$(-22.1)\ (31.5) \qquad [9.11]$$

Each individual pair of coefficients, as well as the entire equational relationship, was subjected to statistical test. Also the correlation coefficients were compared for each pair of equations to determine relative "goodness" of fit.

As a result of the statistical tests, one would be led to reject the hypothesis that the coefficients describing the three types of driving time requirements were the same in both time periods. Thus, the new combined driving time relationship becomes:[5] $T_1 = 41.38 + 1.85M + .588C$.

Of interest is the observation that from 1950 to 1959 the average route distance increased from 38.60 to 46.98 miles and the number of customers per route decreased from 23.64 to 14.26. The corresponding equation for the 1950 study was $T'_1 = 34.48 + 2.12M + 1.01C$.

In the direct delivery time relationship, a significant change was noted in the type of service performed ($X$). In 1959, over 75 per cent of the observed deliveries included servicing the milk display case. Less than 20 per cent included this service in 1950. To enable proper comparison, the 1950 time-volume relationship was adjusted to include the additional service. In view of the fact that these relationships were fitted graphically through the use of group means, rather than mathematically, it was not feasible to make statistical tests regarding the probability that the observations contained in the 1950 and the 1959 studies were drawn from the same population. However, the following conditions with respect to the nature of the data were noted:

meters; and 2, the 1959 parameters; $S^2$ is the variance; $R^2$, the correlation coefficient squared; $k$, the number of parameters in the two separate regressions; $n$, the number of observations; and $N = n_1 + n_2$. The total route mileage, $M = m_1 + m_2 + m_3$, and the total driving time $T_1 = t_1 + t_2 + t_3$.

[5] The coefficient associated with mileage (1.85) was obtained by weighing the coefficients by the proportion of the mileage traveled in each phase.

(1) The number of delivery time observations was much greater in the 1950 study—2,689 compared to 424 in the 1959 analysis.

(2) The variation in observed time requirements was quite large, and this variance increased greatly with increases in the volume delivered.

(3) The 1950 equation, when adjusted to include ice box service, explained 82 per cent of the variation in the time requirements of delivery, but tended to underestimate time requirements for the smaller volume deliveries.

On *a priori* grounds the decision was made to use the 1950 time-volume relationship, adjusted to include display case service.[6] The primary basis for this decision was that the much larger 1950 sample tended to average out the effect of random variations in time requirements resulting from factors other than the volume of product delivered. These random variations, which are responsible for the high variance among observations, could explain most of the differences between the 1950 and the 1959 studies.

Intensive analysis of the 1950 data revealed that the functions relating direct delivery time and volume per delivery were not linear and that the relatively simple curve types (such as second degree parabolas) that could be fitted mathematically were not appropriate over the entire range of the data. Therefore two functions were used—a second degree parabola to explain the relationship for volumes from 0 to 377 and a linear function for volumes over 377 labor units:[7]

$$T_2 = 3.52 + 0.08869V_s - .0000806V_s^2 \qquad \text{for } V_s \leq 377$$

$$T_2 = 14.95 + 0.0280V_s \qquad \text{for } V_s \geq 377$$

Miscellaneous time requirements increased from 75.4 minutes to 88.3 minutes, hence $T_3 = 88.3$.

Aggregation of the three time components gives us a new relationship for labor as follows:[8]

$$\begin{aligned} TT &= T_1 + T_2C + T_3 \\ &= 129.68 + 4.108C + (.08869V_s - .0000806V_s^2)C + 1.85M \quad \text{for } V_s < 377 \\ &= 1.29.68 + 15.538C + (.0280V_s)C + 1.85M \quad \text{for } V_s \geq 377 \end{aligned}$$

A comparison of the original truck cost relationship with data from current cost studies conducted by the Bureau of Milk Stabilization would

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[6] The use of the adjusted 1950 relationship is equivalent to accepting the hypothesis that the two samples were drawn from the same population.

[7] The 1950 relationship was: $T'_2 = 3.33 + .08556\ V_s - .0000806\ V_s^2$ for $V_s < 377$ and $T'_2 = 14.76 + .02487V_s$ for $V_s \geq 377$. The time requirement ($T_s$) for display case service was $T_s = 0.19 + .00313V_s$.

[8] The 1950 relationship was: $TT' = 109.8 + 4.34C + (.08556V_s - .0000806\ V_s^2)C + 2.12M$ for $\overline{V}_s < 377$; $TT' = 109.8 + 15.77C + (0.02487V_s)C + 2.12M$ for $\overline{V}_s \geq 377$.

not lead one to reject the null hypothesis. Thus, truck cost as a function of route volume remains as follows: $C_t = \$4.59 + .002378V_r$.

These results indicate that, for the range of tolerance specified, significant changes did occur in the input-output relationships underlying the costs of delivering milk at wholesale in California. Direct delivery time requirements increased, but the decreases in driving-time requirements had the effect of modifying the impact on total costs.

In making adjustments to synthetic data to account for the various types of changes, temporal changes in wage rates ($W$) can easily be handled by observing labor agreements in the market area and substituting the new $W$ into the analysis. Changes in average route mileage, "typical" delivery services, and institutional arrangements can be determined by periodic surveys (in California this is regularly incorporated as a part of periodic processing and distribution cost surveys). Compared to the cost of the time studies which were used to develop the original input-output relations, these surveys are relatively inexpensive.

Adjustments of the basic input-output function require an approach that more closely resembles complete reanalysis. It is the belief of the authors, a premise partially supported by this analysis, that reliable estimates of temporal changes can be determined on the basis of a much smaller, and thus less expensive, sample than is required to develop the original relationships.

## THE ROLE OF INDUSTRIAL DEVELOPMENT AS A FACTOR INFLUENCING MIGRATION TO AND FROM WISCONSIN COUNTIES, 1940-1950

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### I. *Introduction*

THE main purpose of this paper is to study the relationship between the movements of population and industrial development in the state of Wisconsin in the 1940's. The analysis purports to test the thesis that migration to and from the 71 counties in the state was contingent not upon the developments in agriculture, but primarily upon those in the field of manufacturing and other non-agricultural activities. Specifically, an attempt is made to verify the argument that only those counties which

* The author is indebted to Professor Richard Muth for his very helpful suggestions and also wishes to thank Professor William D. Knight for many critical comments on an earlier draft of this paper. The help of Professor Harry R. Rymer and his staff at the Computing Center (Dearborn Observatory) of Northwestern University is herewith also gratefully acknowledged. Responsibility for the analysis and conclusions rest however, with the author.

succeeded in attracting industry were able to gain population via in-migration in the decade 1940-1950.

The population of Wisconsin rose by 296,988 persons, or 9.5 per cent, in that decade.[1] However, not all parts of the state and thus not all counties shared equally in the population rise. Population actually decreased in 34 counties, and 20 additional counties had population gains that were less than the state average. Thus, only 17 counties had population increases exceeding the state average.

These population changes can be resolved into two components: (a) the natural growth of the population, that is, the excess of births over deaths during the ten-year period, and (b) the migration of the population, that is, the movement of persons into and out of the state.

Wisconsin's natural growth of population during the 1940's amounted to 370,183, or 11.8 per cent of its 1940 population.[2] However, 73,195 persons migrated[3] from the state in the same period of time, an amount equal to 2.3 per cent of the state's 1940 population. The net result was a population gain of 296,988 persons, noted previously.

An analysis of these two components of population change by counties discloses that only 13 counties retained their natural increase in population and additionally gained population through in-migration. The remaining 58 counties experienced out-migration; of these, 24 counties gained population despite the fact that they did not retain all their natural increase in population, and 34 counties not only did not retain all their natural increase in population, but actually had a smaller population in 1950 than in 1940. This is shown in Chart I.

Chart I demonstrates that migration losses were heaviest in the northern, western, and central parts of the state. This is where the seven counties with the largest negative migration ratios[4] are located. Population

[1] This percentage increase was less than that for the country as a whole (14.5%). It may be pointed out that the figure for Wisconsin compares also unfavorably with those for other states in the same geographic region, such as Michigan (21.2%), Ohio (15.0%), Indiana (14.8%), and Illinois (10.3%).

[2] The data on excess of births over deaths were developed from the statistics provided by the Wisconsin State Board of Health, as reported in M. J. Hagood and E. F. Sharp, *Rural-Urban Migration in Wisconsin, 1940-1950* (Agr. Expt. Sta., U. of Wis., Res. Bul. 176, Aug. 1951).

[3] The migration data for the state and the individual counties were derived as follows: The excess of births over deaths was added to the 1940 population and then the 1950 population was subtracted from that sum. In-migration resulted when the 1950 population exceeded the sum of 1940 population plus the excess of births over deaths. It should be stressed that the migration figures used in this study do not agree with those given in the Hagood and Sharp report, because the latter utilized preliminary and this study the final 1950 Census figures.

[4] The concept "net migration ratio," as understood in this study, stands for the ratio of net migration change for a given county in the 1940's to that county's population in the year 1940.

gains were chiefly in the southeast, which is where all the counties with the largest positive migration ratios are located.

Turning our attention to economic considerations, the 1940's were characterized by a very rapid growth of the national economy. Gross National Product, measured in terms of constant dollars, rose by approximately 40 per cent and employment by about 25 per cent. The state of Wisconsin has fully participated in that growth, and following the national pattern, two tendencies can be singled out as those which best characterized the changing economic status of the state in the 1940's.

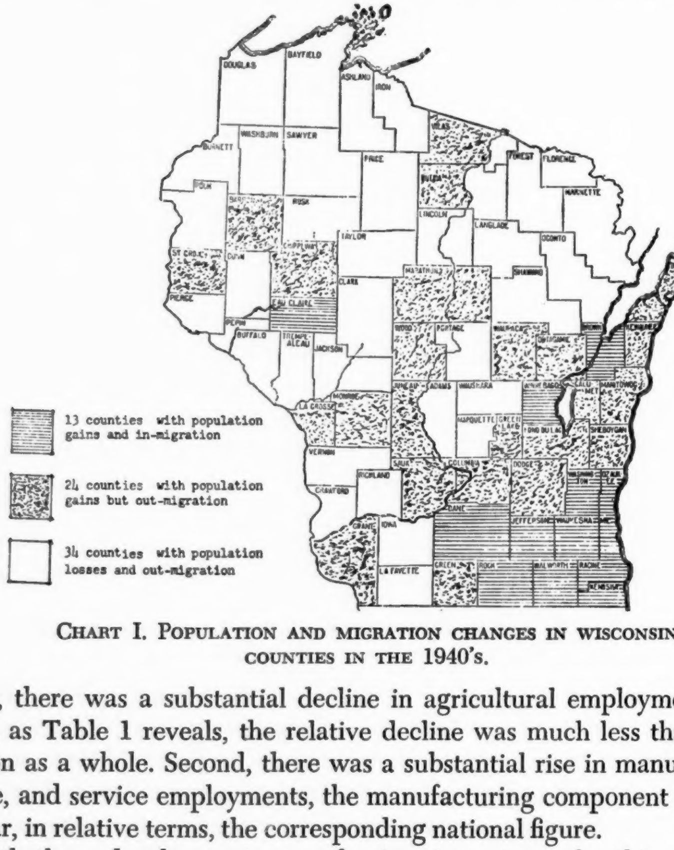


CHART I. POPULATION AND MIGRATION CHANGES IN WISCONSIN COUNTIES IN THE 1940's.

First, there was a substantial decline in agricultural employment. However, as Table 1 reveals, the relative decline was much less than for the nation as a whole. Second, there was a substantial rise in manufacturing, trade, and service employments, the manufacturing component exceeding by far, in relative terms, the corresponding national figure.

Both these developments are of prime importance for this study, and we must devote more space to them.

### *Developments in Wisconsin agriculture*

The declining role of agriculture in the Wisconsin economy is best demonstrated by the figures reflecting the share of agricultural employment in total employment in the state. Thus, while 25.8 per cent of all

persons employed in the state were engaged in agriculture in 1940, that percentage figure dropped to 18.6 in 1950. In absolute terms, agricultural employment decreased by about 21,500, at the same time when total employment was increasing by 294,500. Of course, these figures do not tell the entire story about the status of agriculture in Wisconsin. For instance, one should note that the value of agricultural production in the state, even after correcting for price increases, rose by 26 per cent in the decade under study. This means that fewer farmers, utilizing improved methods and equipment and operating larger farms, were able to achieve a substantial increase in total output.[5]

TABLE 1. OCCUPATIONAL DISTRIBUTION OF THE WORKING POPULATION IN WISCONSIN AND THE UNITED STATES, 1940 AND 1950

| Area and Occupation | 1940 | | 1950 | | Absolute Change | Relative Change |
|---|---|---|---|---|---|---|
| | Total | Percent | Total | Percent | | |
| *Wisconsin* | | | | | | *percent* |
| Manufacturing | 270,231 | 25.5 | 414,643 | 30.6 | 144,412 | 53.4 |
| Agriculture | 273,447 | 25.8 | 251,930 | 18.6 | −21,517 | − 7.9 |
| Trade | 167,521 | 15.8 | 233,789 | 17.2 | 66,268 | 39.6 |
| Services | 293,266 | 27.6 | 357,149 | 26.4 | 63,883 | 21.8 |
| Others | 56,293 | 5.3 | 97,772 | 7.2 | 41,479 | 73.7 |
| Totals | 1,060,758 | 100.0 | 1,355,283 | 100.0 | 294,525 | 27.8 |
| *United States* | | | | | | |
| Manufacturing | 10,572,842 | 23.4 | 14,575,703 | 25.9 | 4,002,861 | 37.9 |
| Agriculture | 8,372,222 | 18.6 | 6,886,423 | 12.2 | −1,485,799 | −17.7 |
| Trade | 7,538,768 | 16.7 | 10,547,563 | 18.8 | 3,008,795 | 39.9 |
| Services | 14,828,376 | 32.8 | 17,664,199 | 31.4 | 2,835,823 | 19.1 |
| Others | 3,853,875 | 8.5 | 6,565,561 | 11.7 | 2,711,686 | 70.4 |
| Totals | 45,166,083 | 100.0 | 56,239,449 | 100.0 | 11,073,366 | 24.5 |

Source: *County and City Data Book: 1952*, pp. 428 and 436, and U. S. Dept. of Commerce, *Census of Population: 1950*, Vol. II, Part 7, pp. 593–601.

These tendencies had no doubt a strong impact on agricultural employment in the individual counties and they led to the departure from farms of a large number of farm operator families as well as a lesser need for hired labor. It is important to note that agricultural employment declined in 61 out of the state's 71 counties.

### *Developments in Wisconsin manufacturing*

Wisconsin's considerable growth in manufacturing activity reflects to a large extent the stimulus provided by the war effort. This found expres-

[5] The following supporting evidence can be cited: (a) the number of tractors on Wisconsin farms rose by 111.4 per cent, from 81,195 in 1940 to 171,623 in 1950, (b) the average size of a farm rose from 132.9 to 137.8 acres, and (c) the number of farms declined from 186,735 to 168,561, or by approximately 10 per cent.

TABLE 2. ABSOLUTE AND RELATIVE CHANGES IN EMPLOYMENT IN WISCONSIN, BY MAJOR INDUSTRY GROUPS, 1940 AND 1950

| Major Industry Group or Groups | | Employment | | Amount of Change in Employment 1940–1950 | Percentage Change in Employment 1940–1950 |
|---|---|---|---|---|---|
| Code No. | Name | 1940 | 1950 | | |
| 35–36 | Machinery | 51,534 | 104,023 | 52,489 | 102 |
| 23 | Apparel & related products | 4,865 | 9,197 | 4,332 | 89 |
| 37 | Transportation equipment | 20,199 | 35,692 | 15,493 | 77 |
| 32 | Stone, clay, & glass products | 3,144 | 5,049 | 1,905 | 61 |
| 27 | Printing & publishing | 14,212 | 22,102 | 7,890 | 56 |
| 28 | Chemicals & allied products | 4,292 | 6,269 | 1,977 | 46 |
| 33–34 | Prim. metals & fabr. metal products | 38,710 | 55,936 | 17,226 | 45 |
| 20 | Food & kindred products | 38,152 | 54,737 | 16,585 | 43 |
| 26 | Pulp, paper & products | 21,996 | 30,250 | 8,254 | 38 |
| 24–25 | Lumber & wood products | 27,598 | 33,653 | 6,055 | 22 |
| 31 | Leather & leather products | 18,482 | 19,169 | 687 | 4 |
| 22 | Textile mill products | 11,418 | 10,677 | −741 | − 6 |
| | All other groups | 15,629 | 27,889 | 12,260 | 78 |
| | Total for all major industry groups | 270,231 | 414,643 | 144,412 | 53 |

Source: U. S. Dept. of Commerce, *Census of Population: 1940*, Part 7, p. 571, and *Census of Population: 1950*, Report P-B 49, Table 30, p. 47.

sion in the considerable expansion of plant facilities of the existing firms and in the development of new branches of industry in the state.

Table 2 illustrates the diverse fortunes of various industries in the state in the 1940's. Most amazing was the growth of the machinery industry, which doubled its labor force in one decade. In fact, the increase in employment in this one industry accounts for one-third of the total rise in manufacturing employment in the state. Also impressive absolute and relative gains were scored by the transportation equipment industry. In contrast, the textile industry was the only one to show a decline in employment in the ten-year span, and definite tendencies toward stagnation were also displayed by the leather industry.

The extent of state-wide industrialization can be perhaps best exemplified by the increase in the ratio of manufacturing employees to counties' populations in all but five counties. This is shown in Chart II.

The following summary also illustrates this tendency:

| Year | Number of Wisconsin Counties With More Than— | | |
|---|---|---|---|
| | 5 | 10 | 15 |
| | —Manufacturing Wage Earners per Hundred of Population | | |
| 1940 | 28 | 10 | 2 |
| 1950 | 41 | 20 | 7 |

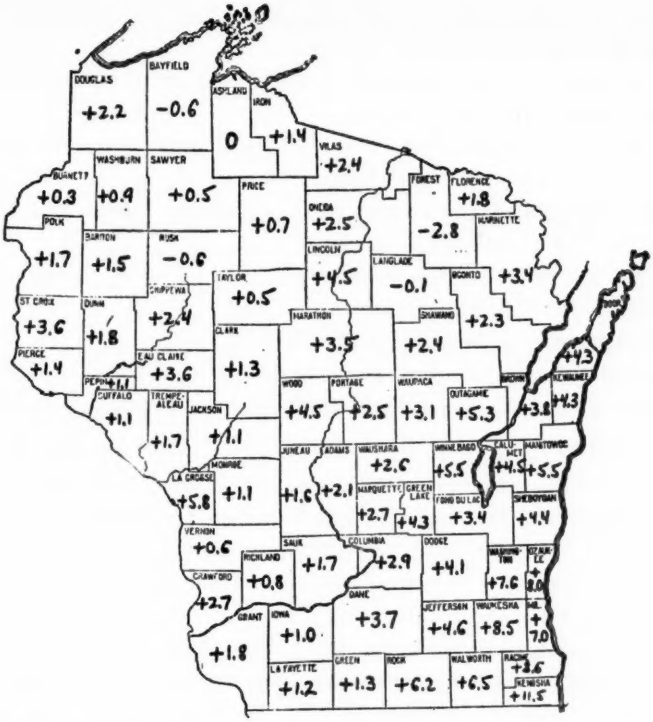


CHART II. NET CHANGE IN MANUFACTURING EMPLOYMENT IN WISCONSIN COUNTIES, 1940-1950, EXPRESSED AS PERCENTAGE OF 1940 POPULATION.

*Developments in Wisconsin trade and services*

The rates of increase in both the trade and service employments in the 1940's have approximated rather closely those for the nation as a whole. In general, the changes in both these fields went hand in hand with the developments in manufacturing.

All Wisconsin counties gained in trade employment and all but two of them gained in service employment. As expected, the largest gains occurred in the counties with a major urban center.

## II. *Testing of Hypothesis*

An attempt will be made in this section to test statistically the hypothesis that migration changes in the 71 Wisconsin counties were essentially contingent upon changes in industrial employment in those counties.

The statistical approach adopted here is based primarily on the multiple correlation technique. The dependent variable $X_1$ and the six independent variables are as follows:

$X_1$ = net migration ratio, or, net migration change in a county divided by its 1940 population;
$X_2$ = net change in agricultural employment in a county, expressed as a ratio to its 1940 population;
$X_3$ = net change in manufacturing employment in a county, expressed as a ratio to its 1940 population;
$X_4$ = net change in trade employment in a county, expressed as a ratio to its 1940 population;
$X_5$ = net change in service employment in a county, expressed as a ratio to its 1940 population;
$X_6$ = median income in each county in 1950;
$X_7$ = population replacement ratio, or the ratio of the 1940 population plus births minus deaths to each county's population in 1940.

The over-all hypothesis is that people migrate in response to income differences, moving to counties where incomes are higher from counties with lower incomes. The independent variable $X_6$ relates to these intrastate earning differences, and one should expect a positive relationship between median income and in-migration. Inasmuch as the dispersion is small, however, the degree of correlation cannot be expected to be high. Other independent variables refer to changes in earnings over the time period considered. Four of these variables are related to employment opportunities in various types of activity. On a priori grounds, one may expect, ceteris paribus, the relationship between these variables and the dependent variable to be positive. This is so because a rise in demand for labor in a given occupation leads to higher earnings, and this tends to attract population. On the other hand, variable $X_7$ reflects the supply conditions. Given unchanged employment opportunities, one should expect a greater supply of labor (that is, a higher population replacement ratio) to lead to lower earnings and hence out-migration. This means that variables $X_1$ and $X_7$ should be negatively correlated.

These results are given in Tables 3 and 4.

All net regression and highest order partial correlation coefficients have the signs I have expected. Net migration changes in the 71 counties are seen to have been closely related to employment opportunities in the manufacturing, trade, and service industries, but not in agriculture. Also, higher income in a county generally meant less out-migration. However, this variable is not significant. Finally, as expected, there was a negative relationship between the net migration and the population replacement ratios.

The hypothesis is accepted on the basis of the "beta" coefficients, which tell us that changes in manufacturing employment had the greatest effect on migration to and from the 71 counties. These changes were about one-

TABLE 3. COEFFICIENTS OF SIMPLE CORRELATION

| Variable | $X_1$ | $X_2$ | $X_3$ | $X_4$ | $X_5$ | $X_6$ |
|---|---|---|---|---|---|---|
| $X_2$ | 0.0870 | | | | | |
| $X_3$ | 0.837 | 0.00224 | | | | |
| $X_4$ | 0.815 | 0.151 | 0.669 | | | |
| $X_5$ | 0.651 | 0.131 | 0.412 | 0.726 | | |
| $X_6$ | 0.782 | 0.294 | 0.785 | 0.761 | 0.546 | |
| $X_7$ | 0.163 | 0.253 | 0.197 | 0.438 | 0.279 | 0.385 |

TABLE 4. MULTIPLE REGRESSION ANALYSIS OF NET MIGRATION RATIOS FOR WISCONSIN COUNTIES, 1940–1950

| Variable | Highest Order Partial Correlation With $X_1$ | Beta Coefficient |
|---|---|---|
| $X_2$ | 0.0706 | 0.0298 |
| $X_3$ | 0.588** | 0.489 |
| $X_4$ | 0.445** | 0.371 |
| $X_5$ | 0.325** | 0.187 |
| $X_6$ | 0.0960 | 0.0754 |
| $X_7$ | −0.396** | −0.184 |

** Significantly different from zero at 0.01 level
$R_{1.234567}{}^2=0.865$, $R_{1.234567}=0.930$
Regression equation:
$X_1=-700+0.217X_2+1.99X_3+4.77X_4+1.48X_5+0.00131X_6-0.656X_7$
The standard error of estimate adjusted for degrees of freedom lost, $s_{1.234567}=3.91$.

third more important than the changes in trade employment, while the latter were twice as important in their effects as variables $X_5$ and $X_7$.

From the multiple regression equation we may also establish by means of a simple transformation,[6] that a county needed, on the average, approximately 7 new manufacturing jobs for each 100 of its 1940 population in order to "break even" with respect to migration, that is, to have no migration gains or losses.

## III. *Industrial Specialization in Wisconsin Counties and Net Migration Changes*

Having established in the preceding section the importance of industrial development in a county, it is interesting to inquire in turn as to the role played by the industrial specialization in a county, keeping in mind the fact, noted in Table 2, that not all major industry groups have experienced similar growth patterns in the 1940's. This section is devoted to this issue. Its prime purpose is to establish a connection between the type

[6] The multiple regression equation is converted into the following form: $X_1 = 1.99X_3 + (-700 + 0.217\overline{X}_2 + 4.77\overline{X}_4 + 1.48\overline{X}_5 + 0.00131\overline{X}_6 - 0.656\overline{X}_7)$. Substituting all the means and setting $X_1$ equal to zero, we solve for $X_3$.

TABLE 5. NET MIGRATION RATIOS OF COUNTIES GROUPED BY LEADING MANUFACTURING INDUSTRY

| Leading Major Industry Group in a County | | Frequency of Occurrence in 1940 | Median Net Migration Ratio |
|---|---|---|---|
| Code No. | Name | | |
| 35-36 | Machinery | 7 | + 3.5 |
| 37 | Transportation equipment | 2 | + 2.7 |
| 22 | Textile mill products | 3 | − 0.4 |
| 31 | Leather and leather products | 5 | − 1.0 |
| 26 | Pulp, paper and products | 8 | − 4.0 |
| 33-34 | Primary metals & fabricated metal products | 3 | − 4.5 |
| 20 | Food & kindred products | 27 | − 8.9 |
| 24-25 | Lumber and wood products | 21 | −17.9 |
| 28 | Chemicals and allied products | 1 | −19.6 |
| | | 78* | |

* Columbia, Fond du Lac, Jefferson, La Crosse, Ozaukee, Sauk, and Walworth counties were listed twice, thus bringing the total of counties to 78.

of the leading[7] manufacturing industry in a county and the movement of people into and from it.

These relationships are summarized in Table 5.

It is found that those counties in which the lumber (I.G. 24-25), food (I.G. 20), metal-fabricating (I.G. 33-34), and paper (I.G. 26) industries were leading generally lost population through migration, while counties in which the machinery (I.G. 35-36) and the transportation equipment (I.G. 37) industries were leading had, on the whole, migration gains.[8] Furthermore, a comparison with the median net migration ratio for the state as a whole of −8.7 discloses that population losses were especially heavy in those counties in which the lumber and food industry groups were leading.

Let us look at these two groups of counties somewhat closer, inasmuch as they include close to two-thirds of all the counties in the state. We find, first of all, that the counties in which the lumber industry provided the majority of jobs in manufacturing experienced the heaviest migration losses. Here belong all the six counties with the greatest negative migration ratios, namely, Forest, Taylor Ashland, Price, Iron, and Bayfield. All these counties are located in the northern half of the state.

In comparison with this group of counties, those counties in which the food industry provided the largest number of manufacturing jobs experienced, on the average, only half as big losses in population through migration. Nevertheless, certain counties (Rusk, Pepin, Buffalo, and Vernon)

[7] The selection was made on the basis of the percentage of employees among the total of industrial employees in a county.

[8] The latter appear to be industries in which Wisconsin has a definite comparative advantage. Of course, it is to be expected that a similar study conducted for another state would find it to have a comparative advantage and thus relatively greater employment gains in some other industries.

experienced net migration losses comparable in intensity to those found in the former group of counties. One may add that most all counties in the latter group are located in western and southwestern Wisconsin and reach into the lower part of the state in easterly direction as far as Waupaca, Waushara, Columbia, Dane,[9] Green, and Dodge counties.

We emerge with the conclusion that the location of a county in the state is, via type of industrial specialization, also an important factor helping us to explain the movements of the population in the state.

Another factor is probably the proximity of a county to greater population concentrations. It has not been incorporated into the statistical analysis and discussion in this paper, but may make an interesting subject of another investigation.

[9] Dane county is somewhat of an exception, insofar as it is the only one in this group with a migration gain in the period under study. This can be explained by the fact that the city of Madison in that county is not only the seat of the state government, but in addition an important educational and medical center.

# TOWARD EFFECTIVE INTEGRATION OF KNOWLEDGE SITUATIONS IN A THEORY OF MANAGERIAL BEHAVIOR[*]

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THIS note presents a modified classification of knowledge situations to assist in their more effective incorporation in a theory of managerial behavior.

## *A "Knowledge Situation" Defined*

The management[1] process is directed toward a number of events. Examples of events might be the purchase of a tractor, the application of a particular fertilizer, the sale of a hay crop, or the adoption of hybrid corn. The manner and extent to which a manager is informed with respect to any such event is termed a "knowledge situation." Such a knowledge situation necessarily includes one or more analytical referents—for example the "cost" of a change in situation.

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[**] Comments from G. L. Johnson, L. V. Manderscheid and W. B. Sundquist have helped in the development of this paper. The authors take full responsibility for the views expressed, however.

[1] For a description of the functions of a farm manager, see: Bradford, Lawrence A., and Glenn L. Johnson, *Farm Management Analysis*, Wiley, New York, 1953, pp. 6-12.

### *The IMS Classification of Knowledge Situations*

Johnson's[2] classification of knowledge situations was used as a basis for a recent empirical study of the reported managerial behavior of 1,075 farmers. This study is known as the Interstate Managerial Survey (IMS).

The classification[3] of knowledge situations used in the IMS was as follows: (1) Subjective certainty, (2) risk action (positive or negative), (3) learning, (4) inaction, and (5) forced action (positive or negative).

### *The Addition of "Involuntary Learning"*

Considerable success has been reported in reconciling this classification of knowledge situations with farmers' alleged behavior. However, some difficulty arose in identifying the negative risk action, the inaction and the positive forced action situations.[4]

Lard[5] claims to have reduced this difficulty by distinguishing between voluntary and involuntary learning. He has accordingly added a new knowledge situation, involuntary learning, which is defined as a situation wherein the manager is unwilling to learn more since the cost of additional information equals or exceeds its value to him, but in which some outside force makes it necessary to learn, or for some learning to occur regardless of the volition of the manager.

Johnson and Lard[6] state that all six knowledge situations (the original IMS situations and Lard's "involuntary learning") are used or needed by farm managers in problem solving.

The revised IMS classification is, of course, still tentative. Its usefulness cannot be adequately demonstrated until a more fully coordinated theory of managerial behavior is evolved. Meanwhile, we believe that it has, in any event, considerable heuristic value.

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[2] The systematic development of knowledge situations in agricultural economics owes much to Glenn L. Johnson. His classification evolves from a study of a number of writers, including F. H. Knight, A. G. Hart, and Abram Wald and empirical work in conjunction with L. A. Bradford, Cecil Haver, and C. F. Lard.

[3] Johnson, Glenn L., and Curtis F. Lard, "Knowledge Situations," chapter in forthcoming IMS "wrap-up" manuscript.

[4] *Ibid.*

[5] Lard, C. F., "An Evaluation of the Interstate Managerial Study Classification of Knowledge Situations," unpub. M.S. Thesis, Mich. State Univ., East Lansing, 1959, p. 56. (Johnson and Lard now claim that this difficulty has been further reduced by redefining a "new technology" as follows: A new technology is the discovery of a new input, where inputs are defined to include ideas. An input will be considered a new technology to an individual farmer until he makes either a positive or negative risk action decision concerning the input, after which the input is an old technology to him.)

[6] Johnson and Lard, *op. cit.*

*Suggested Addition of a Further Knowledge Situation*

Lard's suggestion of the need for further discrimination between the voluntary and the involuntary learning situations raises a further question. This question might well have been raised on logical grounds alone much earlier, *viz.*, why the continued asymmetry in the classification of voluntary and involuntary situations, introduced initially by the recognition of positive risk action and positive forced action situations, and now only partially reduced by Lard's modification?

Notwithstanding the contentious aspects of some of the data available to Lard, the very fact that his extension of the classification of knowledge situations was induced by an attempt to explain some otherwise puzzling facets of these data encourages consideration of a further symmetrical extension. We accordingly suggest that it is just as reasonable for an entrepreneur to entertain either voluntary or forced inaction, and we define forced inaction as follows:

A *forced inaction* situation, with respect to a particular event conceivably relevant to an entrepreneur, is a situation in which the entrepreneur thinks he has enough information to act and would otherwise enter a (voluntary) learning or a positive risk action situation except that he is restrained from doing so by circumstances beyond his immediate control. The inhibiting circumstances could be one or more of many factors including, for example, the likelihood of general social censure and the personal importance attached to it, physical limitations on the entrepreneur (including sickness), and so on.

A forced inaction situation is distinguished from a voluntary inaction situation because only the former is associated with an ability on the part of the manager to *recognize* preferable alternative, but currently unattainable, courses of action. Conformity with a negative risk action or a negative forced action involves conscious modification of the future choice of actions, which precludes immediate subsequent consideration of at least one alternative still considered by a manager in a forced inaction situation, *ceteris paribus*.

For example, a dairy farmer might be forced to reduce the rations fed to his cows and so restrict the level of production he could subsequently attain. Such a reduction in rations could be a negative forced action. A corresponding forced inaction would be the continued use of the original rations. This forced inaction would not restrict future short-run attainable levels of milk production as severely as the corresponding negative forced action.

A summary listing of suggested knowledge situations, under assumed practical conditions, follows:

| *Voluntary Knowledge Situations* | *Corresponding Involuntary Situations*[7] |
|---|---|
| subjective certainty (a limiting case) | subjective certainty (a limiting case) |
| positive risk action | positive forced action |
| negative risk action | negative forced action |
| (voluntary) learning | (involuntary) learning (L) |
| (voluntary) inaction | (forced) inaction (B) |

### *The Importance of Distinguishing Between Voluntary and Involuntary Knowledge Situations*[8]

We now hazard some further generalizations on the importance of distinguishing between the forced or involuntary situations and the corresponding voluntary situations. First, it seems likely that the limiting conditions for involuntary situations may be more readily specified. By definition, these situations depend upon circumstances external to the decision-making entity of immediate concern. Since many of them are likely dependent on factors external to the business, these factors should be more readily identifiable. Identification of situations generally beyond the control of entrepreneurs should assist both in the prediction of adjustment responses and in the determination of the problems most urgently in need of attention by policy makers.

The involuntary situations have thus far been defined from the vantage point of the individual entrepreneur. What one entrepreneur *thinks* is a forced situation may not seem so to another. Yet it is reasonable to assume that it is the entrepreneur's view of the situation that governs his actions. Some of this diversity in assessment of what situations *are* forced may be thought to be due to the varying competence of the entrepreneurs. The "better" entrepreneur can plausibly be thought to *anticipate* organizational difficulties to a greater extent and to make early provision on a voluntary basis. This avoids the development of a forced situation that would later confront a less competent entrepreneur under otherwise simi-

[7] The knowledge situation originally proposed by Lard is indicated by (L); the further situation now proposed is indicated by (B).

[8] An example of the observed possible importance of this distinction is as follows: A recent analysis of the reasons why 5,967 milk producers entered or left the Detroit, Cleveland, or Toledo milk markets during the period from January 1, 1953 to July 1, 1956 revealed, among other things, that these milk producers "have, or exhibit, little choice in the selection of a market." More than 60 percent of the producers considered no other market than the one they joined. (See Kampe, R. E., "Factors Influencing the Decision of Milk Producers Who Entered and Left the Detroit, Cleveland and Toledo Milk Markets," unpub. M.S. Thesis, Mich. State Univ., East Lansing, 1959, p. 164.) Farmers' adoption of bulk milk tanks may correspond to either voluntary or involuntary knowledge situations. (See, for example, Ranney, W. P., "Returns from Selected Dairy Herds in the Nashville Milkshed," Tenn. Agr. Expt. Sta. Bul. 281, Knoxville, Jan. 1958, p. 17.)

lar original conditions. *Ceteris paribus,* we would then expect the more competent entrepreneur, on the average, to be confronted with significantly fewer involuntary situations than his less competent counterpart. The suggested *ceteris paribus* conditions we most need to relax to enable a comparison of actual entrepreneurs include the "luck" element, the initial resource distribution and discriminatory structural conditions external to the individual business.

### *An Illustration of How the Extended Classification May Contribute to an Explanation of Managerial Behavior*

One of the main reasons for Lard's original suggested addition of the involuntary learning knowledge situation was that it would enable an explanation of the transition from learning or inaction situations to some other knowledge situation. The additional knowledge situation now suggested is intended to facilitate still further explanation of the farmer's transition from one knowledge situation to another. Some examples of plausible sequences of knowledge situations follow. These examples tend to emphasize the needed reference to an event in defining a knowledge situation.

The failure of a hay crop for a man who is unable to buy more hay (a likely forced inaction) may induce him to cull some dairy cows as rapidly as possible, as he will be unable to maintain their production over an extended period and feed the rest of his livestock as well. This rapid culling may be a positive forced action with respect to the milk production event. In the meantime, he may have been compelled to reduce the rations of other livestock—a *negative* forced action with respect to the originally comtemplated event (*i.e.*, maintaining the original ration) but also a *positive* forced action with respect to the emerging "ration reduction" event.

For another example, a man accustomed to fattening steers may be aware of some "good buys" and be otherwise willing to take advantage of them, but an unexpected failure of his grain crop may compel him to remain in a forced inaction situation with respect to these "buys" and to let the opportunity to purchase the animals go by. The forced inaction situation has emerged, in this instance, as a direct result of an involuntary learning situation with respect to a subsidiary event, *viz.*, feed procurement.

### *Summary*

The IMS classification of knowledge situations included (1) subjective certainty, (2) risk action, (3) learning, (4) inaction, and (5) forced action. We have illustrated the likely fruitfulness of extending this classification to include two new knowledge situations, *viz.*, involuntary learning and forced inaction. This extension involves both empirical and logical considerations.

# DEMAND ELASTICITY IN THE FACTOR MARKET AS IMPLIED BY COBB-DOUGLAS PRODUCTION FUNCTIONS

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IT IS generally agreed that the demand for most farm resources is sometimes inelastic. In particular, we would expect the demand for farm land, labor and capital to be highly inelastic at both the firm and the industry levels in the short run.

If it is granted that an economic analysis of the best quantity of resources to use on farms should allow for the possibility of inelastic demands in the factor markets, then Cobb-Douglas analysis is not appropriate. The Cobb-Douglas production function implicitly assumes an elastic demand for all factors of production used under conditions of diminishing returns. Other frequently used production functions such as the parabola and the square root equation have inelastic demand responses for some levels of factor use.

Take, for example, the Cobb-Douglas production function for a single factor $X$ used in the production of a single product $Y$ under the conditions of diminishing returns:

$$Y = aX^b \qquad 0 < b < 1$$

The analysis of this single factor case is sufficiently general if it is assumed that the constant $a$ term includes the effect of other factors of production fixed at given levels of use.

The derived demand for the factor $X$ is reflected in the marginal value product curve:

$$P_x = P_y baX^{b-1}$$

where $P_x$ and $P_y$ are the prices of the factor and the product respectively.

From the demand equation, the elasticity is found to be

$$\eta = \frac{dX}{dP_x} \cdot \frac{P_x}{X} = -\frac{1}{1-b}$$

which means, for example, that if $b$ is one-half, the elasticity is $-2$. It is evident that

$$0 < b < 1 \Rightarrow -\infty < \eta < -1$$

and inelastic demand schedules are precluded in the factor market for Cobb-Douglas production functions with diminishing returns.

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## REVIEWS

*Freedom to Farm*, Ezra Taft Benson. Garden City, New York: Doubleday & Company, Inc., 1960. Pp. 239. $3.95.

Presumably Secretary Benson wrote this book to influence the farm policy views of his party, its Presidential nominee, and the general public while he still commanded the prestige of his office. After nearly eight as wearing years as any Secretary of Agriculture ever had, Mr. Benson was still demonstrating his faith in his beliefs and an unflagging willingness to fight for them. He wrote the book not to express new ideas but to assert again the soundness of old ones.

His method is to give an historical account of the federal government's intervention in farm economic affairs since World War I. He sees this history as a recurring demonstration of the wrongness and futility of government's attempts to modify free markets or to infringe on farmers' freedom of decision. His is not the best or most complete history available, but it often is an interesting one because of its views on the motivations of some of the men who have most influenced farm policy and for fragments of information not presented elsewhere.

Mr. Benson summarizes his program for agriculture in five points: (1) eliminate controls and base support prices on recent market prices, (2) gradually expand the conservation reserve, (3) step up "Food for Peace," (4) continue research on new uses and new crops, and (5) assist the little farmer by such means as the Rural Development Program.

Agricultural economists may read the book more for what it reflects about the man who has played so important a role in farm policy than for the history it relates. He seems uncomfortable with statistics: a discussion of labor productivity data (pp. 134-5) suggests he does not quite understand them, and he offers the rise in dollar value of farm production in World War I as evidence that "output rose amazingly" (p. 173). His beliefs and his information at times seem insulated from each other. At one point he writes, "Studies by economists of the Department of Agriculture indicate that the continued adoption of existing farm technology will give us a potential for the production of an overabundance of food and fiber right through the forseeable future" (p. 218). But he sees no implications for his program, and 15 pages later he writes, "What today may seem like unwanted surpluses may be replaced with deficiencies in a few years as new mouths and new economic resources come into being."

Mr. Benson says of a commonsense statement by Seaman Knapp, "In the deeper meaning of that statement is the faith of free enterprise, of the eternal religious principle of free agency applied to the everyday business of earning a living." Economic policy, this seems to say, merges with and

is an extension of theology. The economic analyst who lives in a world of poorly measured probabilities and is afflicted by a tendency to see at least two sides of a question may admire, even envy, the positiveness and fortitude derived from this approach. But he may still insist that economics is a field for reason rather than for dogma and that Mr. Benson's vision of the attributes of a free society is a highly arbitrary and rigid one.

G. E. BRANDOW

*Pennsylvania State University*

*Land for the Future,* Marion Clawson, R. Burnell Held, and Charles H. Stoddard. Baltimore: The Johns Hopkins Press, 1960. Pp. xvi, 570. $8.50.

*Land for the Future* sets itself a formidable task. Authors with less fortitude than Clawson and company would have shied from the goal of considering ". . . the changing uses of land in the United States, historically, at present, and in the light of expectations extending to the year 2,000." A comprehensive summary of past and present land use in this country is a big job in itself. To focus on 40 years of future is an even bigger job and takes considerably more courage. Even though the book is not intended as a college text, professors of land economics will draw on it freely for outside reading. Chapter 1, "The Land in Time and Space," is recommended especially for this use.

None of us has a crystal ball that will reflect the shape of things to come. Unlike Mr. Scrooge, we have no Marlo to show the future before it arrives. But we can guess at future events by reasoning from the past and by specifying the assumptions within which we project our estimate of the future. We can say, in effect, that if A and B are true, C must follow. This is essentially the reasoning used in *Land for the Future.*

This method places a special burden on the assumptions or framework within which the future is cast. The reader is cautioned to pay close attention to pages 3 to 17 of the introduction. In these pages, the authors specify their framework with respect to population growth, distribution of income, trends in leisure, prices, and institutions. If time proves this framework to be in error, much that follows will be in error too.

Following the introduction, the authors insert a fairly long chapter describing the relation of land to man. In it, they talk about land as an economic good. In it also they raise the questions that are the subject of the entire book. Basically they are asking, How can we make our land satisfy the demands placed upon it by a growing, modern, urbanized society?

The authors examine first the needs for land and the use of land in the past, present, and future for each of the major use categories—urban, recreation, agriculture, forestry, grazing, and miscellaneous. This is the main body of the book. They follow this with a chapter on future land use, in

which they treat, in the aggregate and by major regions, the combinations of uses that make up the total demand for land.

Each major chapter on a type of land use—urban, agriculture, and so on—contains a wealth of information designed to help evaluate where we are and where we are headed with respect to the use in question. The connection between the facts presented and the questions to be answered is not always very clear. In the chapter on agricultural land use, for example, a discussion of internal organization of farms seems to have little to do with total demand for cropland.

The chapter on future land use is somewhat disappointing after the reader has survived the wealth of detail in the foregoing sections. He will feel rather let down when he finds that, after all, major uses of land will change very little in total acreage in the next 40 years. Major changes will be within uses and will consist chiefly of intensification of use with no significant shifts among uses.

The intensification process itself, especially in connection with agricultural and recreational land, may be quite important. The tendency in the last quarter-century to substitute the more productive land for the poorer areas in crops likely will continue. In agriculture, the increase in capital and the decrease in labor applied to land has helped to change output both in total and per acre to a degree undreamed of 40 years ago. What will happen in the next 40 years is anyone's guess, but one can infer from current trends that the changes in the land, labor, and capital mix are only well started, and that yield and output have limits beyond our boldest guesses.

Recreational use of land is rapidly absorbing more capital and more labor per unit of land and is likely to continue to do so. Although our grandchildren may not use so much land per capita for recreation as is now available, doubtless they will use it more intensively than we now do.

A rapid increase in urbanization has occurred since 1945, and particularly since 1950. Although the acreage of former farmland actually built up is a relatively small percentage of the total agricultural acreage, the authors estimate that by the year 2,000, urban acres may occupy 2½ times the 1950 area. The total area used for urban expansion may not be large, but the quality of the land on which houses are built may cause increasing concern.

Despite some shortcomings, this book performs a useful function. It brings together under one cover a great body of facts and analysis about the economics of land that could be had only with great difficulty, if at all, from dozens of other books, reports, monographs, and unpublished sources. It draws freely on these sources. The authors have done a good and useful service in bringing together, summarizing, condensing, and interpreting a wealth of knowledge about past and future land use in the

United States. The future may prove them wrong, but they have done a courageous and thorough job of analyzing man's relation to land—past, present, and future. Without the courage to look into our future, we may find ourselves regretting our past.

M. L. UPCHURCH

*Agricultural Research Service*

*Food, Land and Manpower in Western Europe*, P. Lamartine Yates. London: Macmillan & Company, Ltd., 1960. Pp. v, 294. 35s.

This is a well-written and authoritative analysis of Western Europe's agriculture—past, present, and future (Western Europe includes countries west of the iron curtain, except Yugoslavia). It is properly oriented to the dominant nonagricultural economies and to the world food trade. The book deserves careful reading by both the professional agricultural economist and the layman who maintains a responsible citizen's healthy interest in affairs vital to his own, and the world economies. Mr. Yates presents his essential thesis succinctly in Chapter 6 as follows, "Indeed it is in the nonagricultural sector that we shall find the chief solution of Western Europe's agricultural problem." He states also in Chapter 9 that Europe could end food imports other than exotics by 1970—if it were a single entity, and if present agricultural policies were to continue. His judgment as to the basic solution to Western Europe's farm problem will ring familiarly to many students of United States agriculture. It is to shift the surplus and low-producing workers, many of whom are only partially employed, from the rural areas and farm employment to urban industrial employment; to increase intra-Western European trade in foods.

Another of Mr. Yates' findings is consistent with changes in the U.S.; some Americans may be surprised to find that this one also applies to Western Europe. This is the extent to which per capita consumption of cereals, and potatoes has declined, while that of meat, eggs, sugar, fats, and certain other foods has increased since 1948. Great improvements in diets have occurred, except in the four Mediterranean countries.

Most of Mr. Yates' highly readable work is devoted to documenting and supporting the above views, but he does not overlook the important matter of identifying and explaining the forces that have prevented, and continue in many instances to block, such shifts from occurring. The more important of these include mistaken philosophies, fallacious government objectives and policies, deterrent effects of national boundaries and trade barriers, and the dead weight of archaic laws and traditions. Here, again-some of the author's comments in identifying specific handicaps are all too familiar; price meddling, definite policies to foster agriculture "as a way of life," refusal to face facts regarding inefficient resource use, and wasted manpower.

Mr. Yates employs an effective and logical organization in developing and presenting his material in *Food, Land and Manpower in Western Europe*. Six parts cover the topic: I—Europe, II—Food, III—Farming, IV—The Modernization of Agriculture, V—Foreign Trade, and VI—The Role of Government. In only one of these, Part III, does he resort to listing countries separately in order to recognize and adequately characterize individual differences. For the rest, he succeeds in establishing a total viewpoint, while developing the flavor of more important country-to-country variations. Any reader who has struggled with the difficulties in accomplishing just this objective while teaching a course dealing with regional agriculture will appreciate the author's skill. The effectiveness with which he summarizes and presents the detailed facts on diets, nutrition, farm resources and organization, and foreign trade patterns without losing the forest among the trees is particularly noteworthy.

This reviewer likes the manner in which Mr. Yates relates variations in these principal agriculturally-oriented characteristics to both causal factors and their effects. He does this for both countries and sub-regions in Western Europe. U.K.'s agriculture is "the most 'tractorized' farming anywhere"; France was for years "the home of romantic peasant worship," but this view is now giving way to a more commercial attitude; industrialization and transferring people out of agriculture is the only hope for the four Mediterranean countries. The author recognizes the importance of soils and climate in regulating production, and, in consequence, exerting heavy influence on diet and nutrition. He insists, however, that human attitudes and goals, inheritance laws and other institutions, and the entire complex of agricultural and related economic policies and regulations are more important. The summary of the factors that cause U.K. agriculture to be unusual for Europe is important from two standpoints. They explain why U.K. largely has solved its farm efficiency problems. Conversely, they identify the favorable forces that the rest of Western Europe lacks in greater or lesser degree: the enclosure movement led to large consolidated farms; the law of primogeniture and *early* industrialization prevented farm subdivision and rural overcrowding; 70 years of free trade forced farming onto a competitive business footing; a substantial return flow of brains and capital moved from city to farm. The recently developed emphasis on increased output has brought more mechanization and greater use of purchased inputs in the U.K. Countries in the Mediterranean area show the greatest contrast to U.K.'s modern and commercially-oriented farmers. Small plots, fragmentation, hand methods, lack of science, and mistaken government policies have dammed up population on the land, wasted manpower, and prevented efficient resource use.

Mr. Yates' suggestions for governmental action to aid in correcting the ills of Western Europe's agriculture are consistent with his analysis of

causes: freeing of prices so that they may perform their market functions; encouragement for excess labor to transfer out of agriculture; and measures to improve technical performance, such as encouragement for farm consolidation and strengthening of research, in order to attain higher output per resource unit. Such is his skill in marshalling his facts and presenting his arguments that this reader would not seriously challenge the author's conclusion that such measures could accomplish great gains for Western Europe's farmers. Perhaps the tentative estimates of "30 percent more food with 20 percent less labor" by 1970, and accompanying reduced unit production costs are not unreasonable. Experience in both the United States and the U.K. would tend to support this contention.

One thing yet should be said; not the smallest pleasure in reading Mr. Yates' work is the enjoyment that one obtains from his gift for expression. This writer appreciates many passages, but finds the following particularly noteworthy: "one can assume that about the middle of the eighteenth century the labour pains presaging the birth of modern industrial society were already being felt in Britain and the Low Countries while conception had certainly taken place in several others."

TRIMBLE R. HEDGES
*University of California*

*The Changing Pattern of Europe's Grocery Trade,* Robert T. Davis. Stanford: Stanford University Press, 1959. Pp. 292. $10.00.

Compared to the advanced technology in West European manufacturing, food processing and distribution is an underdeveloped sector of most of the economies. A 1960 snapshot of the European situation carries an American observer back at least a quarter century into our own history. From the American viewpoint, the food trade in Europe is simply an oversized museum of outmoded institutions and inefficient methods. For the tourist, it's all very picturesque, to be sure.

Professor Davis who, during the academic year 1957-58, taught Marketing at the University of Lausanne (Institute for Study of Management Methods), describes—in considerable detail and with excellent documentation—the status of food processing and distribution in Switzerland, Great Britain and the Common Market countries (France, Holland, Belgium, Italy and West Germany). He compares the development of marketing channels for food in Europe with what has happened in the United States. Dr. Davis is at his analytical best in trying to explain why Europe is so far behind in adapting self-service, supermarkets, pre-packaging, private branding, mass pre-selling through national advertising, price competition, horizontal and vertical integration, and marketing research. One gets the impression that most of the 150-odd executives

whom Professor Davis interviewed knew a great deal about American institutions and had a sound respect for our mass distribution philosophy and practice. They were equally knowledgeable about why "it would not work here," and gave Davis the whole gamut of reasons: European companies are small; they are owner-managed by founders or inherited in the unbreakable chain of nepotism; subordinates are incapable of handling responsibilities, thus preventing decentralization; people are unusually individualistic; managers are brilliant practitioners of the seat-of-the-pants approach and can therefore adequately solve their problems on the basis of judgment and experience alone. . . . Davis tears apart many of these rationalizations. He shows that 20-30 years ago, U.S. "expert-rationalizers" knew equally well why self-service and pre-packaging would not be acceptable, and how they ended up eating their words many times over.

In his well balanced analysis of individual countries, Davis readily concedes that there are some important structural differences. Yet they are merely challenges that the imaginative and courageous innovators can exploit. The major obstacle seems to be psychological: European food processing and distribution is not consumer oriented. The trade is overly concerned with the "smallness" or "fixity" of the market. Under these circumstances, the "pie" has to be "fairly" distributed among the participants. Powerful trade associations and cartels do the prorating among those who promise not to rock the boat by price competition and other "subversive" behavior. The innovator is not welcome because he disturbs the elaborate equilibrium.

The quick economic growth experienced in Western Europe in the last decade, combined with economic integration, is confronting, for the first time, the food processors and distributors with a buyer's market. Some "heretics" are exploiting the chinks in the protective armor of the traditional cartels. Davis presents several case studies of these "deviationists." The most fascinating is the famous Migros chain in Switzerland, which is clearing the path for many American innovations. Gottlieb Duttweiler, the dynamic president of this organization, has just received the first International Marketing Award from Michigan State University for his pioneering. More recently, the Leclerc discount stores have stirred up much constructive unrest in France. . . . Progress can simply not be cartelized away. For those who would like to get on the progressive bandwagon, Davis sketches out four alternative marketing strategies.

This is an extremely useful book that should be eagerly welcomed by practicing economists, teachers, marketing researchers, and the entire food industry (producers, processors, wholesalers, retailers, advertisers and consumers) on both sides of the Atlantic.

FRANK MEISSNER

*San Jose State College*

*Economics of Agriculture,* W. W. Wilcox and W. W. Cochrane. New York: Prentice-Hall, Inc., 1960, 2nd edition. Pp. iii, 538. $8.75.

This edition of *Economics of Agriculture* represents a major reorganization and updating of subject matter presented in the first edition. The book is divided into six major parts. Part I is concerned with "Production of Farm Products." Emphasis is placed upon input-output relations, comparative advantage, and the supply of agricultural products. Very little attention is devoted to an analysis of the possibilities of substitution of inputs in production. Perhaps, this accounts for the authors' unacceptable definition of farm technological advance—"a recombination of factor-inputs in a farm enterprise such that the output from the enterprise increases with the same total input of factors measured in dollar terms" (p. 54). The emphasis upon a dollar measure of inputs in this definition completely disregards the scale effects of changes in the prices of inputs.

Part II is concerned with "Marketing of Farm Products." It contains an interesting and informative discussion of the nature of the marketing system, its changing structure, marketing services and costs, and market demand. The discussion of the changing structure of farm markets is especially well done.

Part III, "Toward an Understanding of Farm Prices," finds the authors at their best. The analyses of the price-income structure of agriculture, of how farm prices are determined, of the roles that prices play, and of farm price problems are quite stimulating. This section of the book is concerned largely with aggregate questions. Most of the treatment of the subject matter is in a context of perfect competition. The reader is surprised, therefore, to learn that the authors renounce perfect competition as an analytical tool and then devote only three pages to a statement of the nature of imperfect competition. The treatment of this subject is entirely too brief to enable the student to receive sufficient knowledge of these concepts to be able to apply them to the economic world.

Part IV, "Farmers in the National and World Economies," is concerned largely with the role of agriculture in the U. S. economy and the role of U. S. agriculture in world markets. Both the cyclical and secular aspects of agricultural development are treated in a clear and interesting manner. The major shortcomings of this section are the very brief discussions of the nature of business fluctuations, including the inventory approach and income-expenditure approach to business cycle analysis, and the misleading connotation attached to the significance of foreign trade in maintaining full employment. The authors argue that two-way trade "does not and cannot contribute directly to the achievement of full employment" (p. 342). They do not recognize, however, that the demand for labor is derived from the demand for finished goods and services and that in as much as two-way trade may increase the demand for goods and services, it may also indirectly increase the demand for labor.

Part V, "Human Resource and Land Policy Problems," is a brief survey of a number of topics pertaining to labor and land use. The authors consider 2.7 million families living in rural areas to constitute a "poverty problem" of the U. S. Since classifications of people into low income categories are quite arbitrary, and since much of the rest of the book is oriented toward factors influencing the incomes of farm people, the reviewer expected more information pertaining to the distribution of income within agriculture and more discussion of the causes of the "poverty problem." With the emphasis that is placed upon technological change in the rest of the book, the reader would like to see a more comprehensive treatment of the relation between this technological change and the development of the poverty problem.

In view of the large volume of research that was published during the 1950's pertaining to conflicts of interest between landlords and tenants in resource use, the reviewer is surprised that the authors neglected these aspects of farm tenancy.

Part VI, "Price Income Policy Problems," traces the growth of government in agriculture and discusses briefly policies which have been used to reduce risk and uncertainty and recent price and income programs in agriculture.

The concluding chapter of the book is on "some unsolved policy issues." This chapter discusses very briefly the major alternatives of agricultural policies that are being considered in the present scene. For example, land retirement programs are discussed in two pages; Cochrane's public utility approach in two pages; other approaches are given even less space. The discussions are, therefore, largely descriptive in nature with little economic analysis of the possible effects of the different programs.

The authors do not indicate the level of training which they regard as prerequisite to an understanding of the subject matter of their book. The reviewer believes that the authors have done a good job of analyzing the major problem areas of American agriculture with the possible exception of the "poverty sector." Students will benefit most from this book, however, if they have a good understanding of the general principles of economics prior to study of the book.

C. E. BISHOP

*North Carolina State College*

*Productivity and Technical Change,* W. E. G. Salter. University of Cambridge, Department of Applied Economics Monograph 6, Cambridge University Press, 1960. Pp. ix, 198. $4.50.

*Productivity and Technical Change* represents a distinguished addition to the series of monographs issued by the Cambridge University Department of Applied Economics.

The first half of the monograph is devoted to a "theoretical analysis of the relationships between movements of productivity, prices, costs, wages and investment in industries experiencing a continuous flow of new techniques" (p. 1). The approach in the second half is "empirical and examines the relationships between movements of productivity, prices, costs, etc., in a number of British and American industries" (p. 2).

Productivity movements are regarded as the net result of a complicated interplay between technical advance and changing factor prices. Technological change is "defined and measured by the relative change in total unit costs when the techniques in each period are those which would minimize unit costs when factor prices are constant" (p. 30). Major attention is given to the problem of separating out the effects of (a) technical factors—primarily arising out of non-neutral technological change—and (b) price factors—primarily changes in factor prices relative to each other —which tend to bias the total productivity (output per unit of total input) measure as an indicator of technological change.

Two aspects of Salter's discussion of the factors which underlie productivity movements deserve special comment:

(1) He presents a particularly interesting discussion of the persistent use of obsolete plant and equipment in the presence of continuous technological change. His model, based on the two principles that (a) technological change is introduced into the production process through capital investment and (b) that capital equipment currently in use will remain in use until its earnings in the form of quasi-rent fall to zero, is similar in many respects to the Johnson-Edwards[1] model recently discussed in this *Journal*. The Johnson-Edwards model, however, achieves somewhat greater analytical power as a result of being more fully developed within the framework of modern production economics.

(2) The discussion of the impact of technological change on the substitution of capital equipment for labor is the most lucid available. It is frequently argued that such substitution represents *prima facie* evidence that technological change has been on balance labor saving. Salter shows, however, that neutral technological change (i.e., technological change which leaves the marginal rate of substitution between capital equipment and labor unchanged) occurring generally throughout the economy will be accompanied by the substitution of capital goods for labor. The "continuous cheapening of capital goods resulting from technical advances in their manufacture . . . automatically generates powerful pressures for the substitution of capital equipment for labor" (p. 30).

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[1] Glen L. Johnson, "The State of Agricultural Supply Analysis," *J. Farm Econ.*, 42: 435-52, May 1960; and Clark Edwards, "Resource Fixity and Farm Organization," *ibid.*, 41:747-59, Nov. 1959.

In the second section of the book, after carefully examining the alternative causes of increased productivity—increased personal efficiency of labor, factor substitution resulting from labor-saving technological change, neutral technological change, and economies of scale—Salter concludes that the explanation has to lie primarily in terms of neutral technological change with perhaps some assist in the form of scale economies. Salter's results are thus consistent with Solow's conclusion that recent technological change in the American economy has been essentially neutral.[2]

Among other important empirical findings of Salter's analysis of productivity in British industry the following deserve particular emphasis: (1) Industries which experienced above average rates of productivity gain tended to pass the results along to consumers in the form of lower relative prices rather than to labor in the form of higher relative wages. (2) Those industries in which the rate of productivity gain was sufficiently rapid to permit declining relative prices were also the industries which experienced the greatest gains in output. (3) In general, output growth in the high productivity gain industries has been sufficient to more than offset employment losses resulting from rising labor productivity—"industries with above-average increases in output per head have also normally recorded above-average increases in employment. . . ." (p. 127).

In comparing these results with a similar analysis based on data for the United States economy, Salter obtains generally similar results except that there was no general tendency in the United States economy between 1923-50 for industries with above-average gains in output per worker to also experience above-average gains in employment.

Salter's book is certainly not the final word on productivity and technological change. The issues raised in the discussion between Schultz and Heady in this *Journal*[3] regarding the relative importance of changes in the quality of the human agent and improvements in the quality of capital inputs are not treated in any depth. The book confines itself to a cross sectional interindustry approach and essentially ignores the issues which center on the relationships between productivity and economic growth. It does, however, represent a better treatment of the conceptual issues involved in interindustry productivity analysis than any of the National Bureau publications including the forthcoming Conference on Research

[2] Solow, Robert M., "Technical Change and the Aggregate Production Function," *Rev. Econ. and Stat.*, 39:312-20, Aug. 1957.

[3] T. W. Schultz, "Reflections on Agricultural Production, Output and Supply," *J. Farm Econ.*, 38:756-60, Aug. 1956; Earl O. Heady, "Output in Relation to Input for the Agricultural Industry," *ibid.*, 40:393-405, May 1958; T. W. Schultz, "Output-Input Relationships Revisited," *ibid.*, 40:924-32, Nov. 1958; Earl O. Heady, "On Output-Input Relationships Revisited: A Reply," *ibid.*, 41:134-36, Feb. 1959.

on Income and Wealth volume on *Output, Input, and Productivity Measurement.*

VERNON W. RUTTAN

*Purdue University*

*Preface to Econometrics (An Introduction to Quantitative Methods in Economics),* Michael J. Brennan, Jr. Cincinnati: South-Western Publishing Co., 1960. Pp. vii, 419. $6.50.

This book, according to the author, is designed for a one-semester course at the junior or senior level. It is intended to provide a comprehensive treatment of quantitative methods that can be understood by undergraduates. Its needed prerequisites are intermediate economic theory, elementary algebra and statistics. The more advanced mathematics that are needed are presented in the text.

The book is divided into five parts. Part I, entitled "Elementary Mathematical Formulation," centers attention on a translation of economics, expressed verbally and with graphs, into the language and concepts of mathematics so that quantitative calculations can be made. Part II, entitled "Elements of Calculus," goes a step farther in the mathematical formulation of economic theory and provides an introduction to the use of the calculus in economics. Part III, "Econometric Models," is an application of Parts I and II, with chapters entitled Static Models, Dynamic Models and the Problem of Uncertainty. Part IV, entitled "Statistical Inference," treats probability theory, sample theory and statistical inference, simple and multiple regression and correlation, and lastly, time series problems. Part V, "Econometric Models Reconsidered," contains four chapters centering attention on refinements in models, the problem of identification, illustrations of econometric research and application to economic policy.

In evaluating this book as a possible text, two questions must be faced at the outset. First, can a course of the type this book is designed for play a useful role in an economics curriculum? Second, how effectively can this specific book be used in the general type of course it is designed to serve?

A one-semester course in econometrics at the junior-senior level, building on a background of intermediate-economic theory and mathematics through algebra, would carry most students not planning to do graduate work in economics much beyond where they usually stop in quantitative economics. Such a course would serve a useful purpose in enabling persons to better appreciate the potential uses of quantitative economics. It might also awaken a student's interest in economics who had previously been exposed to economics with little emphasis on application. On the other hand, a student, knowing ahead of time he wished to do graduate

work in economics, would likely be wise to omit this type of course and take several courses that would enable him to continue forward in his studies rather than to have to fill "gaps" in his background at a later date.

This volume, if properly used, would in my opinion be an effective teaching aid. The problems at the end of each chapter would likely prove especially effective. In my opinion, this volume should be used as a "laboratory manual" in what might be labeled an economics laboratory course. Thus the focus of the course would be on problem solving or application and the lecture part of the course incidental to the above.

My belief is that any student that could solve all the problems the author has placed at the ends of the chapters would be far ahead of even the better student majoring in economics at the undergraduate level. Such an objective in a one-semester course is, I think, an ambitious and perhaps an attainable goal—at least as an instructor it would be fun to have a go at it; to find out how much "understanding" the student would get in working through the exercises.

A further comment may be appropriate. Some instructors would likely wish to treat some subjects the author has omitted and to skip some of the included materials. This does not seem to be a major problem, since many supplementary texts now exist in the areas covered by the book, and such adjustments could likely be fitted into the over-all outline of the book.

In summary, the author has put his finger on a major gap in the "education" of undergraduates in economics; his prescription of a one-semester course to fill the gap, however inadequate, is probably about as much as can be expected; his book appears to be a useful tool to aid in closing this gap and enabling students to appreciate the power and limitations of quantitative analysis.

GEORGE K. BRINEGAR

*University of Illinois*

*The Theory of Linear Economic Models*, David Gale. New York: McGraw-Hill Book Company, 1960. Pp. xxi, 330. $9.50.

This book is a welcome addition to the growing set of literature in the area of linear programming and the related linear models. Perhaps it is wise to state at the outset of this review that, although the word economic appears in the title, this is not a text in economics but in applied mathematics. The book is written by a mathematician and is intended as a text for students in pure and applied mathematics. As a result, topics have been selected on the basis of those models which best indicate how mathematical reasoning can be used to obtain information about idealized economic situations. Consequently, little attention is devoted to the applicability of the abstract models formulated and the justification of their

economic assumptions. The unifying force which ties together the collection of problems of an economic flavor is the mathematics of real linear algebra or, in more common language, the theory of linear equations and inequalities in real numbers. The specific feature of this theory which plays the unifying role in most of the economic applications is the fundamental notion of duality.

The book starts by describing the linear programming problem first by means of a set of illustrative examples and then by formal definition. Since the central results of linear programming theory concern the relationship between a problem and its dual, the fundamental duality theorem is stated and illustrated. Following this introduction to the subject there is a presentation of the mathematics (real linear algebra) needed for an understanding of the subsequent topics to be covered.

Given this mathematical machinery, linear programming problems are then defined in complete generality and the duality and equilibrium theorems, along with the result on basic solutions, are given full coverage. Of special interest to the economist is the application of linear programming to the solution of the problem of optimal resource allocation by the method of price equilibrium under free competition. The simplex method is then introduced and applied, not only to linear programming but also to general problems which involve systems of inequalities and finding non-negative solutions to linear equations. The discussion is then directed to the class of linear programs that have integral solutions if the initial data are integral.[1] Here the transportation problem, as well as various other applications, are treated in detail.

The discussion then moves to nonoptimization models which have the characteristic feature of individuals or groups with conflicting interests. The two-person zero sum game is introduced and a proof of the Von Neumann Minimax theorem is given. The equivalence of linear programming and matrix games is shown and some discussion is given to solving games by the simplex method.

The final sections of the book are of special interest to economists. These sections begin by a discussion of linear models of exchange and are concerned with such matters as balance of trade, flow of income, and price equilibrium under special types of exchange situations. Building on the work of Solow, a dynamic theory of linear trade models is treated using the theory of Markov chains in probability theory. Theorems relating to the existence and uniqueness of equilibrium prices in these linear models are then developed.

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[1] It is somewhat unfortunate that the recent work of Gomory and others on the solution of integer programming problems could not be included. Those persons interested in these recent developments are referred by the reviewer to the following article: Gomory, R. E., and Baumol, W. J., "Integer Programming and Pricing," *Econometrica*, 28:521-50, 1960.

The book concludes with a discussion of linear models of production. Leontief input-output models are developed and the Samuelson-Koopmans-Arrow substitutability theorem is given along with its proof. The work of Koopmans on the relation between efficiency and profit maximization and Von Neumann's expanding linear model are the final topics considered.

The format followed for each of the topics presented in this book is as follows: first, the economic situation is described; next, a statement is made regarding the simplified specification; and then a purely abstract formulation is given. Each chapter ends with a short set of bibliographical references and a set of exercises of varying degrees of difficulty. Some of the proofs presented are quite difficult and in order to further the reader's understanding, such devices as geometric pictures, plausibility arguments and numerical examples are used.

There is little doubt that this book will make an excellent text for graduate students in applied mathematics. There is little doubt also that graduate students in economics and agricultural economics should have a grasp of the topics covered by this book. Unfortunately, given the level of rigor on which the analysis in this book proceeds, only an agricultural economics graduate student with exceptional aptitude for the mathematical approach will find this book appropriate for self study. However, if one has the ability to follow a moderately involved mathematical argument, this book offers much in terms of insight and training in formulating models and then deducing in a rigorous fashion the consequences of the assumptions which have been made. Therefore, the book should be welcomed by teachers of mathematical economics and should serve as an excellent supplementary text to such books as "Linear Programming and Economic Analysis" by Dorfman, Samuelson and Solow or "Mathematical Economics" by Allen.

Professional workers in agricultural economics who are interested in the subject of linear models will find in this book a mathematically unified treatment of the new results over the last 10 to 15 years which were previously available only in scattered sources in the economic and mathematical literature. Many who read the book will also agree that it is a worth-while endeavor to look at some parts of pure economics through the eyes and pen of an applied mathematician. Although this book will probably not be widely read or used by agricultural economists, those who are willing to spend the time necessary to work through it will be rewarded by being brought up to the frontiers of the subject of linear economic models and put in a position to understand and possibly contribute to current research in this field.

GEORGE G. JUDGE

*University of Illinois*

## ALEXANDER EDMOND CANCE, 1872-1960

ALEXANDER E. CANCE, Professor Emeritus of the University of Massachusetts and one of the pioneers in agricultural economics, died at his home in Winter Park, Florida, November 17, 1960. Born in Wisconsin at a time when the Granger movement was sweeping the West, he later gave life in the classroom to the economic and social forces of the last quarter of the 19th century that contributed to shaping national policy for agriculture, transportation, resource development, and cooperation.

Dr. Cance joined the staff of the then Massachusetts Agricultural College in 1909. There he organized and was the first Head of the Department of Agricultural Economics. Forty years ago he reviewed the research being done in agricultural economics and sociology and his report, presented to the Association of Land Grant Colleges, helped bring into being the Purnell Act.

He is best known, however, for his work in agricultural cooperation, and was honored for his sustained interest and contribution by the Institute of Cooperation at the 1948 annual meeting held in Amherst.

Dr. Cance retired from academic life in 1942. He received many honors. None, however, meant so much to him as the regard and affection of his students.

# NEWS NOTES

RONALD A. ANDERSON was appointed Assistant in Agricultural Economics at North Dakota State University in October.

FRANK T. BACHMURA, who has been in Santiago, Chile, for 1½ years on a Fulbright Fellowship, joined the staff of the Farm Economics Research Division, ARS, in October.

MERTON B. BADENHOP, University of Tennessee, has accepted a two-year extension of his appointment under the U.T./INDIA/ICA contract in India and will continue to be headquartered in Bangalore.

FRANK M. BAKER retired in February 1960 as Director of the Field Services of the Meat Packers Council in Western Canada after 35 years with the Council.

HENRY H. BAKKEN, University of Wisconsin, has received an honorary recognition award from the Wisconsin Association of Cooperatives. The citation read, "For his bold and effective intellectual leadership in the promotion of cooperatives. For his valuable contributions to the literature of the cooperative movement, for his active participation in numerous kinds of cooperatives and his valued counsel and guidance."

RANDOLPH BARKER, Agricultural Economist, Farm Economics Research Division, USDA, located at Cornell, has received the title of Assistant Professor from Cornell.

ALFRED L. BARR joined the Washington, D.C., staff of the Farm Economics Research Division, ARS, in September.

WILLIAM BARRY, County Agricultural Agent in Columbia County, New York, worked in Farm Management Extension at Cornell during November and December. He was responsible for organizing and conducting a series of income tax schools.

LEWIS A. BAUMAN has transferred from the Marketing Economics Research Division to the Market Quality Research Divion, AMS.

H. WALTER BAUMGARTNER, who received the Ph.D. degree at the University of Minnesota in December, has accepted a position as Economic Analyst in the State of Minnesota Department of Employment and Security.

SIDNEY C. BELL, who recently completed requirements for the Ph.D. at Michigan State University, has been appointed Farm Management Specialist with the Extension Service at Auburn University.

WILLIAM S. BENNETT, Farm Economics Research Division, ARS, formerly stationed at Shelbyville, Ky., is now at Lexington, Ky.

ROBERT BENTZ, who completed the requirements for the Ph.D. at Louisiana State University in December, has been appointed to the Extension staff at L.S.U. to work in poultry marketing.

JOSEPH P. BINIEK joined the Atlanta, Ga., staff of the Farm Economics Research Division, ARS, in September.

MILTON B. BLACKWOOD has been named as Canadian Trade Commissioner at Djakarta, Indonesia.

ROY W. BLAKE has become Assistant Director, Agriculture and Fisheries Branch, Department of Trade and Commerce, Ottawa. He previously served the department in several overseas posts.

LAWRENCE L. BOGER, Head of the Agricultural Economics Department at

Michigan State University, began a three month administrative sabbatical on December 1, 1960. He will devote his time to study and writing. During his leave DALE HATHAWAY is serving as Head of Department.

CLARENCE C. BOWEN, Department of Agricultural Economics and Rural Sociology at Ohio State University, has been promoted to Assistant Professor.

WAYNE E. BOYET, formerly with the Baton Rouge, La., staff of the Farm Economics Research Division, ARS, resigned in September.

NELLIS A. BRISCOE has been promoted to the rank of Associate Professor at Oklahoma State University.

THOMAS M. BROOKS has joined the Marketing Economics Research Division, Agricultural Marketing Service. He recently received his Ph.D. from Pennsylvania State University.

ALLEN J. BROWN has been appointed Agricultural Economist with the Alabama Agricultural Extension Service and will be engaged in full-time Extension work as a poultry marketing specialist.

MEYER BROWNSTONE has been appointed Deputy Minister of the Saskatchewan Department of Municipal Affairs, Regina, Saskatchewan.

HARRISON M. BRYCE has been appointed Assistant Agricultural Economist at Auburn University. He will be engaged in full-time research on economic development problems incident to Auburn University contract research with the U. S. Study Commission, Southeast River Basins.

MARGUERITE C. BURK, AMS, began in January a special assignment with FAO in connection with the Third World Food Survey.

CHARLES A. CAMERON was appointed Executive Secretary of the Dairy Farmers of Canada, succeeding ERLE KITCHEN, who retired on July 31 after 30 years of service. Mr. Cameron was employed for the past several years by the Metropolitan Co-operative Milk Producers' Bargaining Agency, which represents 91 co-operatives in New York, Pennsylvania, New Jersey, Vermont, Maryland and Delaware.

D. R. CAMPBELL, Ontario Agricultural College, has been appointed a member of the executive of the Social Science Research Council of Canada.

ROBERT H. CAMPBELL has joined the staff of the Special Projects Section of the Agriculture Division of the Dominion Bureau of Statistics, Ottawa. Mr. Campbell was formerly with the Production Economics Section of the Economics Division, Canada Department of Agriculture, Ottawa.

RAY CARPENTER, Farm Economics Research Division, ARS, is on leave to study for his master's degree at the Ontario Agricultural College, Guelph.

DONALD E. CARR joined the staff of the Farm Economics Research Division, ARS, in October, and is stationed at Davis, Calif.

W. FRED CHAPMAN has transferred from the Washington, D.C., office to the Gainesville, Florida, office of the Marketing Economics Research Division, AMS.

WALTER CHRYST, Farm Economics Research Division, ARS, is on leave to serve with ECLA/UN from November 1, 1960, to December 1, 1961, on a study of economic integration in Central America, with headquarters in San Jose, Costa Rica.

PAUL C. CLAYTON, Department of Agricultural Economics and Rural Sociology at Ohio State University, has been promoted to Associate Professor.

FREDERIC A. COFFEY moved from the Oklahoma City Office of the State Statistician, Agricultural Estimates Division, AMS, to the Agricultural Surveys Branch in Washington, D.C., on January 8.

HOWARD E. CONKLIN, Cornell University, spent a month last fall in Venezuela. He participated in the completion of the land classification project which he helped to start in 1959 for Consejo de Bienestar, Automercado 'Las Mercedes'.

GARY DEVINO completed his Master's degree in August and is working full time for a year in milk marketing at Cornell.

JOHN L. DILLON was appointed Senior Lecturer in Agricultural Economics in the Faculty of Economics of the University of Adelaide, South Australia, effective Jan. 1.

LARRY D. DINGUS resigned in August from the staff of the Farm Economics Research Division, ARS, at Columbia, Mo.

HAROLD V. EDWARDS transferred on January 8 from the Livestock and Poultry Statistics Branch in Washington, D.C., Agricultural Estimates Division, AMS, to the Office of the State Statistician at St. Paul, Minnesota.

CARL EICHER has been appointed assistant professor at Michigan State University effective February 15. He has just completed his doctorate at Harvard, and will devote his time to studies in international economic development.

THEO H. ELLIS has resigned from the Farm Economics Research Division, ARS, to accept a position as Associate Agricultural Economist at Auburn University. He will conduct research in farm management and production economics and will serve as Associate Director of the University's IBM Computer Center.

GERALD ENGELMAN, Head of the Livestock Section, Marketing Economics Research Division, AMS, is visiting professor in the Department of Agricultural Economics at the University of Minnesota during the winter quarter.

JEAN C. EVANS, formerly Professor at the National Agricultural Extension Center for Advanced Study, University of Wisconsin, has been appointed Assistant Director of the University of Missouri Extension Service and Professor of Agricultural Economics.

ERNEST FEDER, University of Nebraska, attended the eleventh Sociological Congress of Mexico, at Cuidad Victoria, November 7-11, where he presented a paper on "Political Aspects of Agrarian Reforms."

WALTER M. FURBAY, who recently completed his Ph.D. in Agricultural Economics at Ohio State University, has accepted a position as Agricultural Economist with the Campbell Soup Company in Camden, New Jersey.

GENE FUTRELL, formerly of Iowa State University, has joined the Department of Agricultural Economics and Rural Sociology at Ohio State University. He will work in the area of Marketing Information for Consumers on the Agricultural Extension staff.

C. H. GREENE has joined the Marketing Economics Research Division, AMS, at Corvallis, Oregon.

DONALD W. GREGG, formerly on the Athens, Ga., staff of the Farm Economics Research Division, ARS, transferred in September to the ARS Data Processing Division.

ZVI GRILICHES has returned to the University of Chicago after being on leave of absence for the past year as Research Associate at the National Bureau of Economic Research in New York.

FRANCIS W. GROVES was appointed an instructor in the Department of Agricultural Economics at the University of Wisconsin on October 1. He will do extension and research in Dairy Marketing.

RUSSELL HANDY transferred in January from Statistician in Charge of the Co-

lumbus, Ohio, Office, Agricultural Estimates Division, AMS, to become Branch Chief of the Fruit and Vegetable Statistics Branch, Agricultural Estimates Division.

JAMES L. HEDRICK, Farm Economics Research Division, ARS, transferred in September from Blacksburg, Va., to Raleigh, N.C.

GEORGE F. HENNING recently returned to Ohio State University after an I.C.A. consulting tour in Turkey.

RICHARD HERDER, research assistant in grain marketing at Kansas State University, is leaving to take a similar position with the Federal Reserve Bank of Minneapolis. He will continue his work toward a Ph.D. degree in economics.

JOE D. HERMAN transferred from the Statistical Standards Division, AMS, to the Agricultural Surveys Branch, Agricultural Estimates Division, on October 16.

OMER W. HERRMANN, Deputy Administrator, Marketing Research, AMS, recently spent a month in the U.S.S.R. as a member of a United States Food Processing Exchange Mission.

PETER HILDEBRAND was appointed associate member of the Graduate Faculty of the Texas A. and M. College.

ARTHUR J. HINTZMAN transferred from the Office of the State Statistician at Lansing, Michigan, Agricultural Estimates Division, AMS, to the Statistical Standards Division, in Washington, D.C., on November 3.

ALLAN D. HOLMES has been promoted to Director of the Prices Division, Dominion Bureau of Statistics, Ottawa. Mr. Holmes was formerly Chief of the Special Projects Section of the Agriculture Division.

IRVIN HOLMES, Fruit and Vegetable Statistics Branch, Agricultural Estimates Division, AMS, retired on December 31, after more than 32 years of service.

OLIVER W. HOLMES, Farm Economics Research Division, ARS, formerly stationed at Bozeman, Mont., is now at Corvallis, Ore.

HERBERT B. HOWELL, Iowa State University (Ames), spent November and December on an assignment with the International Cooperation Administration to consult with the Argentine Government on beef production.

JOHN M. HUIE has been appointed Assistant in Rural Sociology at Auburn University and will be engaged in full-time research on problems of social and economic adjustments in low-income rural areas of Alabama.

JAMES R. HURST has resigned as Assistant in Agricultural Economics at Auburn University to accept a position with the Alabama Agricultural Extension Service of Auburn University.

J. DEAN JANSMAN, Farm Economics Research Division, ARS, is now stationed at Stillwater, Okla.

ALBERT R. JOHNSON has joined the staff of the World Bank in the Agricultural Division of its Department of Technical Operations. He was formerly with the Technical Review Staff, U. S. Department of the Interior.

W. BERT JOHNSON, Chief, Marketing Research and Statistical Programs Branch, Marketing Information Division, AMS, has left USDA for a tour of duty for the Ford Foundation on a project seeking to raise the agricultural productivity of India. WAYNE DEXTER is replacing Mr. Johnson.

A. D. JONES has joined the staff of the Marketing Economics Research Division, AMS. He received his Ph.D. degree from Texas A. and M. College.

ROBERT R. JONES, assistant professor in agricultural economics, who has been

working with projects concerning communication of economic information to laymen, has left Kansas State University to do similar work in commercial publications, working with a Milwaukee-based firm.

A. S. KAHLON has completed his work toward the first Ph.D. degree ever to be granted in Economics at Kansas State University and has returned to India to a post with the Indian Government.

C. DEL MAR KEARL, Cornell University, is spending a one-semester leave in Uganda doing farm management advisory work.

JAMES R. KENDALL transferred on January 8 from the Field Crops Statistics Branch, Agricultural Estimates Division, AMS, in Washington, D.C., to the Office of the State Statistician in Columbus, Ohio, where he will be in charge of the Office.

WILLIAM E. KIBLER, transferred from the Office of the State Statistician in Athens, Georgia, Agricultural Estimates Division, AMS, to the Office of the State Statistician at Raleigh, North Carolina, on September 12.

JOHN A. KINCANNON was recently promoted to Associate Professor in the Department of Agricultural Economics and Sociology, Texas A. and M. College.

NATHAN KOENIG, in charge of Legislative Reports, AMS, has completed a detailed assignment with the Senate Interior and Insular Affairs Committee on an economic study of American Samoa. The purpose of the study was to determine what should be done to improve the economy so as to raise the standard of living of the Samoan people and provide a basis for more self-government. A printed report will be available early this spring.

TEIICHI KYONO, of Hokkaido University, is a visiting professor this academic year in the Department of Agricultural Economics at the University of Massachusetts.

MAX LANGHAM, who will receive his Ph.D. from the University of Illinois in February 1961, has been appointed Assistant Professor of Agricultural Economics at Louisianna State University.

WILLIAM J. LANHAM, Farm Economics Research Division, ARS, transferred from Clemson, S.C., to Raleigh, N.C., in September.

LORNE W. LEGGATT has been appointed Assistant Manager of the Manitoba Agricultural Credit Corporation.

CARL B. LEWIS, formerly with the Manhattan, Kan., staff of the Farm Economics Research Division, ARS, has transferred to the Department of Interior, stationed at Grand Island, Nebr.

ERVEN J. LONG, former Head of the Department of Agricultural Economics at University of Tennessee, and for the past four and one-half years Group Leader of the U.T./INDIA/ICA Contract Group in India, has resigned to accept a position with International Cooperation Administration in Washington, D.C.

CHARLES D. MADDOX has been appointed Agricultural Economist with the Alabama Agricultural Extension Service and will be engaged in full-time Extension work as a farm management specialist.

WILLIAM E. MARTIN, who has recently completed the requirements for the Ph.D. at the University of California, joined the staff of the Department of Agricultural Economics, University of Arizona on December 1, as Assistant Professor. His work will be primarily in the field of Production Economics.

ROBERT MCELROY, Farm Economics Research Division, ARS, is on leave to take graduate work at Pennsylvania State University.

VERNON C. MCKEE, who recently completed course requirements for the Ph.D. at Iowa State University, joined the Washington, D.C., staff of the Farm Economics Research Division, ARS, in October.

BENNY R. MCMANUS has resigned from the Alabama Agricultural Extension Service to accept a position as Assistant in Agricultural Economics at Auburn University and will be engaged in full-time research on grain marketing.

JOHN G. MCNEELY served as ICA consultant in Argentina in September and October, assisting in the planning of the economic phase of Operation Beef.

GUY W. MILLER recently returned to Ohio State University after a nine month tour of duty in Pakistan as an advisor to the World Bank.

JARVIS E. MILLER was recently promoted to Associate Professor in the Department of Agricultural Economics and Sociology, Texas A. and M. College.

KENNETH E. MILLER, formerly manager of the Economic Research Department, Armour and Company, has been appointed Professor of Agricultural Economics and Research Associate in the Bureau of Business and Economic Research, University of Missouri.

LEONARD F. MILLER, Oklahoma State University, left on September 26, as a member of a team making a study of university programs in the Near East. Particular emphasis was placed on the teaching and research programs of the Imperial Ethiopian College of Agriculture, which is sponsored by Oklahoma State University. He returned in December.

PAUL L. MILLER, Senior Marketing Specialist in the Market Orders Branch of the Dairy Division, AMS, retired on November 30, after more than 42 years of service.

WILLIAM C. MOTES, formerly a cooperative agent with the Marketing Economics Research Division, AMS, stationed at Ames, Iowa, has transferred to the Washington, D.C., office. He recently received his Ph.D. from Iowa State University.

GEORGE C. B. MURRAY has been appointed Research Advisor to the Research and Statistics Division, Department of Veterans' Affairs, Ottawa. He was formerly with the Farm Finance Section of the Agriculture Division, Dominion Bureau of Statistics, Ottawa.

RICHARD H. NEWBERG, Department of Agricultural Economics and Rural Sociology at Ohio State University, has been promoted to Professor.

HAROLD L. NIX has resigned as Assistant Rural Sociologist at Auburn University to accept a position in full-time teaching at Georgia State College in Atlanta, Georgia.

GEORGE OWEN, Chief of the Loans Division of the Farm Credit Corporation, Ottawa, has been appointed Vice-Chairman of the Corporation, and will carry out the duties of both positions.

GEORGE R. PATTERSON has been appointed Canadian Consul General in Los Angeles. Mr. Patterson was formerly Director of the Agriculture and Fisheries Branch, Department of Trade and Commerce, Ottawa.

HOWARD L. PATTERSON, Director of the Farm Economics and Statistics Branch, Ontario Department of Agriculture, has been appointed Chairman of a special committee to study problems confronting Ontario agriculture due to the grain surplus. Other committee members are: S. H. LANE, Ontario Agricultural College; JULIAN SMITH, Marketing Director of the United Cooperatives of Ontario; and BRUCE TEASDALE, member of the Farm Products Marketing Board.

ROBERT PAWLEY, formerly Veterans' Land Act superintendent at London, Ontario, was appointed Director of VLA in Ottawa.

B. B. PERKINS, Ontario Agricultural College, has resigned to pursue further graduate work at Michigan State University.

LEVI A. POWELL has joined the Marketing Economics Research Division, AMS, in Washington, D.C. He comes from the University of Florida.

ROBERT REED has resigned from the Berkeley, California, office, Marketing Economics Research Division, AMS, to accept employment with the United Fruit Company.

ROBERT E. RIECK was appointed instructor in the Department of Agricultural Economics at the University of Wisconsin on December 1. He will do extension and research in Farm Management.

ROBERT L. RIZEK has been appointed a cooperative agent of the Marketing Economics Research Division, AMS, and is stationed at Ames, Iowa.

WILLIAM E. ROBINSON, Assistant to the President of the American Stock Yards Association, accepted appointment November 1, as Potato Marketing Specialist in the Extension Service, University of Maine.

BOYD B. ROSE has resigned as Assistant in Agricultural Economics at Auburn University to accept a position as Assistant Agricultural Economist at the University of Georgia. He will be engaged in full-time research on rural and economic development and related problems.

REGINALD ROYSTON, Chief, Fruit and Vegetable Statistics Branch, Agricultural Estimates Division, AMS, retired on January 7, after more than 35 years of service.

F. O. SARGENT, land economist at the Ontario Agricultural College, has been appointed a member of the Conservation Council of Ontario.

T. W. SCHULTZ spent last summer in Russia and western Europe. He was chairman of a team of six American economists who spent a month in Russia, under the sponsorship of the Committee for Economic Development, as guests of the Academy of Sciences of the U.S.S.R. The Academy of Sciences, following the wishes of the team, scheduled 45 formal meetings for the American economists. These meetings were with administrators, managers and economists at the all Union level and at the regional and also at the republic levels. (Three of the republics were included—the Ukraine, Georgia, and Uzbek.) Plants producing both consumer and producer goods were included, as well as Gosplan at highest administration level. Following this stay in the U.S.S.R., the group spent several days in Warsaw pursuing a similar course of discussions. Professor Schultz then went to Lake Como, Italy, where he participated in a ten-day conference on the Economic Aspects of Education.

EDGAR T. SHAUDYS, Department of Agricultural Economics and Rural Sociology at Ohio State University, has been promoted to Associate Professor.

ROBERT S. SMITH, Cornell University, is spending a one-year sabbatic leave as a Farm Management Adviser to the Israeli Extension Service.

ERLING D. SOLBERG, Agricultural Economist, Land and Water Research Branch, ARS, will be visiting professor in the Department of Agricultural Economics at the University of Minnesota during the winter quarter 1961.

H. B. SORENSEN was recently promoted to full member of the Graduate Faculty of the Texas A. and M. College.

R. G. SPITZE has resigned from the University of Tennessee to accept a position at the University of Illinois.

LYNN STANTON completed his Master's degree in September and is working full time for the coming year with the Farm Management Extension staff at Cornell.

MILTON H. STEINMUELLER resigned in September from the Pullman, Wash., staff of the Farm Economics Research Division, ARS.

RANDALL STELLY was recently promoted to Associate Professor in the Department of Agricultural Economics and Sociology, Texas A. and M. College.

CHARLES SWARTZ of the Saskatchewan Economic and Advisory Planning Board has been appointed technical consultant and Acting Executive Director of the Saskatchewan Crop Insurance Board.

GARY C. TAYLOR, Farm Economics Research Division, ARS, is now stationed at Berkeley, Calif.

MARLOWE M. TAYLOR, Farm Economics Research Division, ARS, transferred in November from State College, N.M. to the Washington, D.C., staff.

PHILLIP J. THAIR, professor of farm management at the University of Saskatchewan and Editor of the *Canadian Journal of Agricultural Economics,* has been appointed Chairman of the Saskatchewan Crop Insurance Board.

G. S. TOLLEY and A. J. COUTU, North Carolina State College, have received a grant from Resources for the Future, Inc., to study the relation of soil conservation to economic development of the Southeast.

THOMAS G. TOON has joined the staff of the Farm Economics Research Division, ARS, and is stationed at Atlanta, Ga.

RAYMOND D. VLASIN, Farm Economics Research Division, ARS, formerly stationed at Madison, Wis., transferred to the Washington, D.C., staff in September.

DENNIS W. WARE has been promoted to Head, Prices and Statistics Unit, Policies and Prices Section, Economics Division, Canada Department of Agriculture, Ottawa. He recently completed the course requirements for the Ph.D. in Agricultural Economics at Ohio State University.

BOYD L. WARNICK joined the staff of the Farm Economics Research Division, ARS, in September and is stationed at Salt Lake City.

CLIFTON R. WHARTON, JR., Associate for the Singapore Region with the Council on Economic and Cultural Affairs, was Visiting Fellow at Cornell University during the fall semester. He also visited agricultural economics departments in a number of other institutions during his home leave.

FLOYD WILLIAMS has joined the staff of the Marketing Economics Research Division, AMS, at Griffin, Georgia. He recently received his Ph.D. from the University of Florida.

WILLARD WOOLF, who is completing his Ph.D. work at Louisiana State University, has been appointed Instructor in Agricultural Economics at L.S.U.

A. B. WOOTEN was recently appointed associate member of the Graduate Faculty of the Texas A. and M. College.

## ORGANIZATIONAL ANNOUNCEMENTS

North Dakota Agricultural College has had its name changed to North Dakota State University of Agriculture and Applied Sciences as a result of the general election November 8, 1960.

In a reorganization of the Agricultural Estimates Division, Agricultural Marketing Service, approved last June 17, the number of commodity sections was

reduced from 18 to 10, through reassignment and consolidation. The former Special Statistics Branch was replaced by a new Agricultural Survey Branch.

The National Science Foundation will sponsor a Summer Institute for College Teachers of Statistics at Iowa State University for the 11-week period from June 5 through August 18, 1961. The Departments of Statistics of three other universities, Kansas State, Utah State and the University of Wyoming, are co-operating with Iowa State's statistical center in presenting this institute.

Financial support in the form of stipends, dependency allowances and travel allowances will be awarded to 50 eligible applicants. All American college and university teachers who are, or who during the 1961-62 academic year will be, required to teach one or more courses in statistics as part of their regular assignments are eligible for consideration.

The institute is planned to provide additional basic training in statistics for present and prospective teachers who, though well-grounded in other fields, have limited backgrounds in statistics. Also it will provide more advanced courses and seminars designed to keep college and university teachers abreast of new developments.

Courses are scheduled in Statistical Methods, Theory of Statistics, Experimental Design, Survey Designs, Topics in Foundations of Probability and Statistics, and Intermediate Applied Decision Theory. In addition, an opportunity will be provided for those interested to observe a demonstration class in Principles of Statistics at the undergraduate level. The faculty will include the institute director, Dr. T. A. Bancroft, director of the Iowa State University Statistical Laboratory and head, Department of Statistics; Dr. R. J. Buehler, associate professor of statistics, Iowa State University; Dr. H. T. David, associate professor of statistics, Iowa State University; Dr. H. C. Fryer, head of the Department of Statistics and Statistical Laboratory director, Kansas State University; Dr. H. O. Hartley, professor of statistics, Iowa State University; the institute associate director, Dr. D. V. Huntsberger, associate professor of statistics, Iowa State University; and Dr. R. L. Hurst, head of the Department of Applied Statistics and Statistical Laboratory director, Utah State University. Guest lecturers will present a series of special seminars.

Requests for information or application forms should be addressed to: The Director, Summer Institute in Statistics, 102 Service Building, Iowa State University, Ames, Iowa.

## OBITUARY

YEHUDA GRUNFELD, who received his Ph.D. at the University of Chicago, and who was to have returned to the Department of Economics there last fall as a visiting professor from his post in the Department of Economics at Hebrew University, Jerusalem, Israel, died last summer in a drowning accident.

# JOINT ANNUAL MEETING OF THE AMERICAN FARM ECONOMIC ASSOCIATION AND THE WESTERN FARM ECONOMICS ASSOCIATION

*Colorado State University, Ft. Collins*

*August 13-16, 1961*

## PRELIMINARY PROGRAM

*Monday Morning, August 14*

9:00 General Session
The New Agricultural Programs—For Better or Worse?

11:00 Presidential Address

*Monday Afternoon, August 14*

2:00 Sectional Meetings
Invited Papers Sections
The Scope Effort of Extension and Agricultural Economics
Adjusting Livestock to the Competition of the 1960's
Emerging Problems in Water Economics
An Appraisal of the Rural Development Program: The First Five Years
Contributed Papers Sections
Agricultural Economics Curriculum
Consumption, Marketing and Prices

*Tuesday Morning, August 15*

9:00 Annual Business Meeting

10:00 General Session
Toward an International Dimension in Agricultural Economics

*Tuesday Afternoon, August 15*

2:00 Sectional Meetings
Invited Papers Sections
Agricultural Grading in the 1960's
Reorganizing Agricultural Economics Extension Work
Significant Changes in Foreign Agriculture Since 1945
Farm Labor and Farm Mobility
Contributed Papers Sections
Land Economics, Farm Finance and Institutional Economics
Farm Management and Production Economics

*Wednesday Morning, August 16*

9:00 Sectional Meetings
Invited Papers Sections
Economic Problems of Southern Forestry
Weather and Crops
Improvement of the Management Resource in Agriculture
Applying Economics in Agricultural Extension
Do Market Structures Influence Market Development?
Economies of Scale in Agricultural Production

## SECTIONAL MEETINGS FOR CONTRIBUTED PAPERS

Contributed papers for sectional meetings in four subject-matter areas are solicited. These areas and their chairmen are:

1. *The Agricultural Economics Curriculum—Graduate and Undergraduate*
—Dean C. Peairs Wilson, Kansas State University, Manhattan, Kansas

2. *Consumption, Marketing and Prices*
—Dr. Richard L. Kohls, Purdue University, Lafayette, Indiana

3. *Land Economics, Farm Finance and Institutional Economics*
—Dr. Charles W. Loomer, University of Wisconsin, Madison, Wisconsin

4. *Farm Management and Production Economics*
—Dr. Wylie D. Goodsell, Agricultural Research Service, U.S.D.A., Washington 25, D.C.

### *Rules for Submitting Contributed Papers*

1. The maximum length of any contributed paper shall be seven double-spaced typewritten pages.
2. The title of the contributed paper to be submitted shall be sent to the chairman of the subject-matter area by May 15, 1961.
3. A draft of the contributed paper shall be submitted to the chairman of the area by June 20, 1961.
4. The maximum number of contributed papers to be presented at any sectional meeting shall be five. In case more than five papers are submitted, it shall be the responsibility of the chairman in consultation with several of his departmental colleagues to select the five papers for presentation at the Annual Meeting.
5. At the time of the Annual Meeting a two-page, double-spaced, typewritten abstract of the paper is to be turned over to the chairman for inclusion in the Proceedings Issue.
6. It is recommended that 50 copies of the contributed papers be brought to the Annual Meeting by the author for distribution to those present.

Specific questions concerning papers to be submitted should be directed to the chairman of the subject-matter area concerned. General questions concerning this aspect of the 1961 Annual Meeting should be directed to M. M. Kelso, General Chairman of the Sectional Meetings for Contributed Papers, University of Arizona, Tucson, Arizona.

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## ANNOUNCEMENT OF DEBATE TOPIC FOR ANNUAL UNDERGRADUATE COMPETITION

The topic to be debated for 1961 is:

> *Resolved that the United States surplus agricultural capacity should be used to stimulate economic growth in the underdeveloped nations of the world.*

This topic was chosen for the following reasons:

1. As a topic it does not penalize the negative or affirmative. There are convincing arguments *on either side.*
2. It is controversial.
3. It is timely. The topic is being debated now. It is a national issue today.
4. There is a wealth of reference material available for supporting either side of the argument.
5. It will be educational for the students involved to dig into a highly controversial, currently important issue in national and agricultural policy for which there appears to be no clear cut answer.

Any institution with a chartered student affiliate of the American Farm Economic Association is eligible to enter one team in the debate, subject to the rules governing debate.

A chartered chapter intending entering a team must so inform the Chairman of the Student Activities Committee, Fred H. Wiegmann, Department of Agricultural Economics, Louisiana State University, Baton Rouge, Louisiana, not later than May 1.

A student speaking contest will also be conducted, as in previous years.

Additional information on the rules and procedures for the debating and speaking contests may be obtained from the Chairman at the above address.

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## CAMPING FACILITIES

Families wishing information regarding mountain lodges, campsites, etc., for the joint meetings should write *at once* to Publicity Chairman, AFEA-WFEA, c/o Economics Department, Colorado State University. Reservations for lodges and cabins need to be made by April. Campsites are on a first-come, first-choice basis.

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